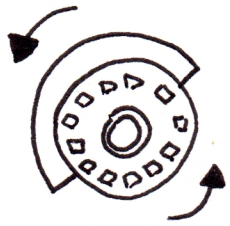
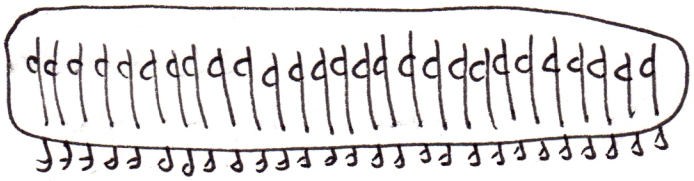
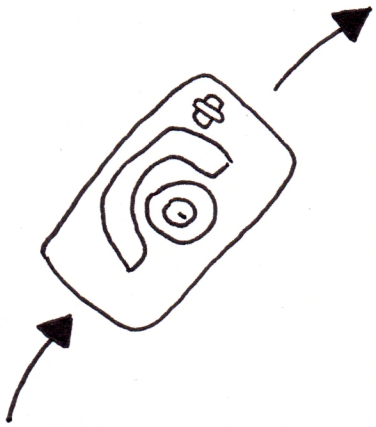
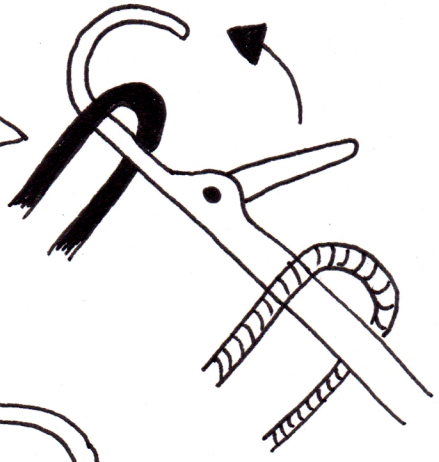
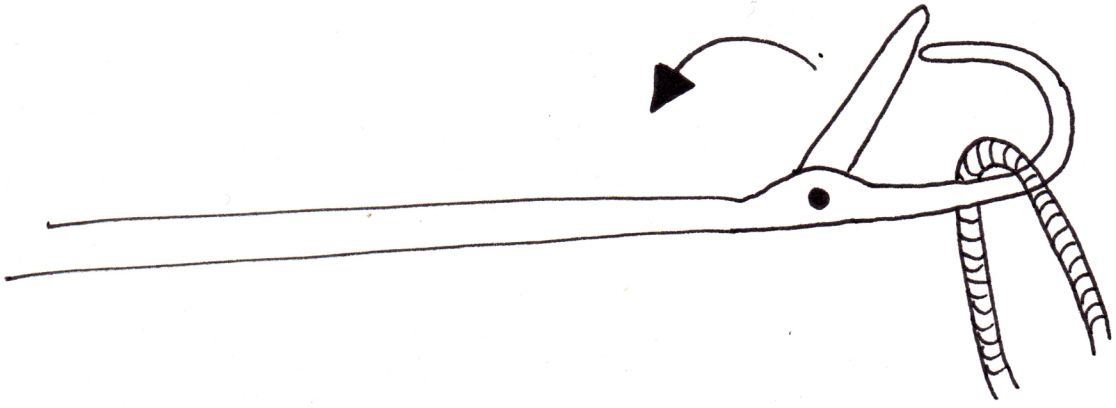




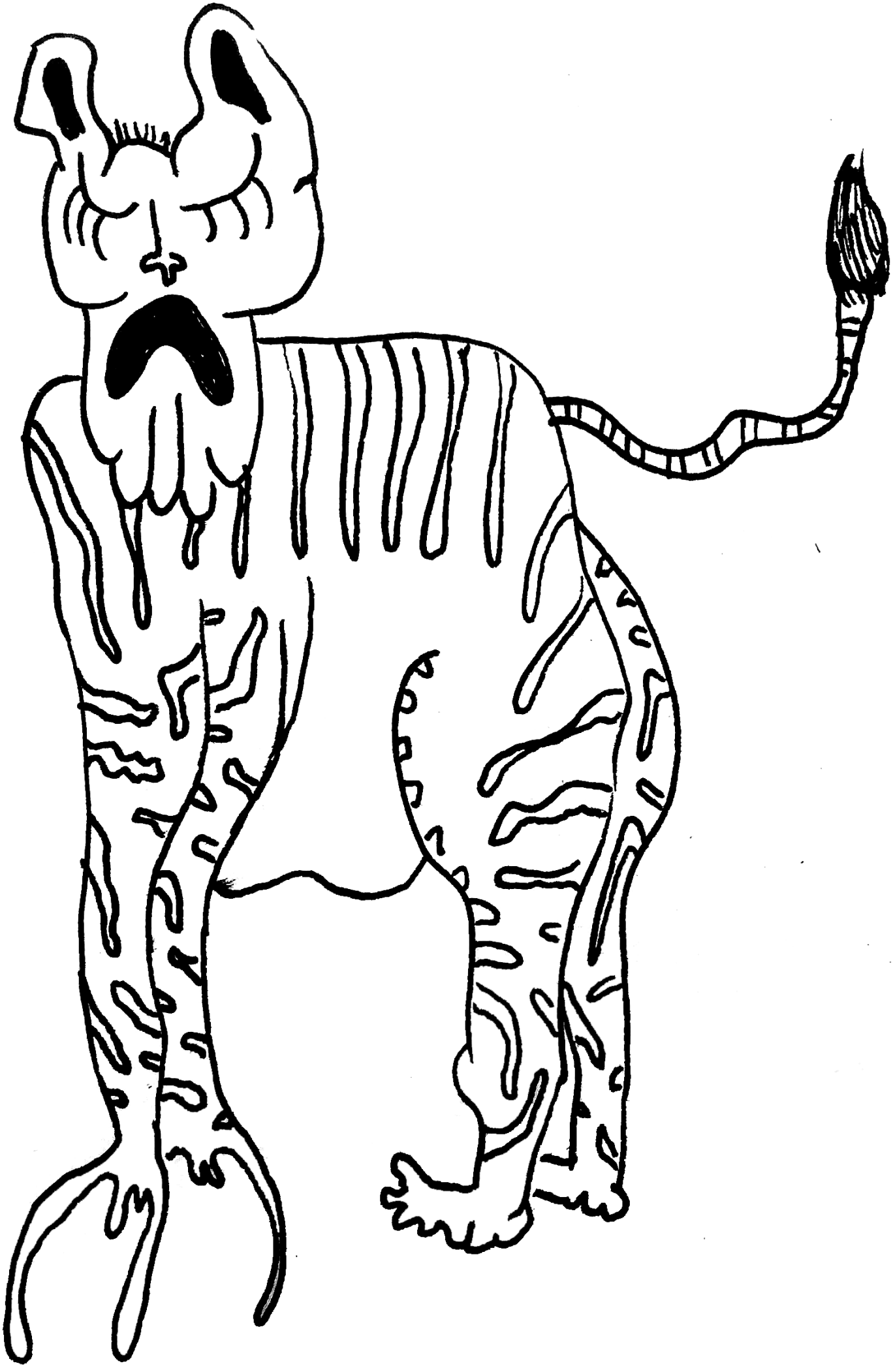
HOW KNITTING MACHINES WORK







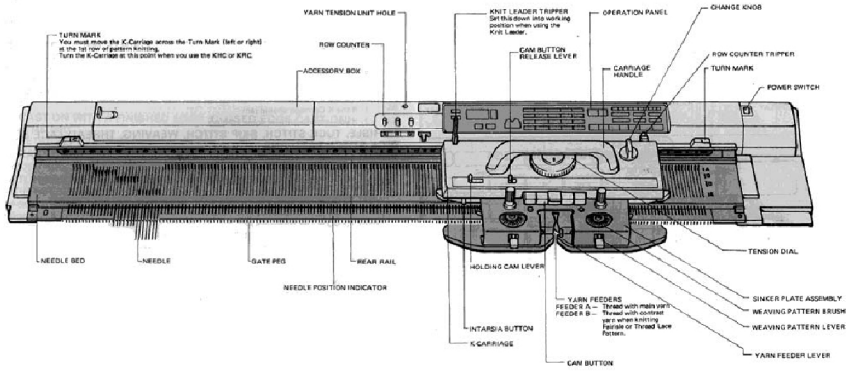
by Tom Hobson



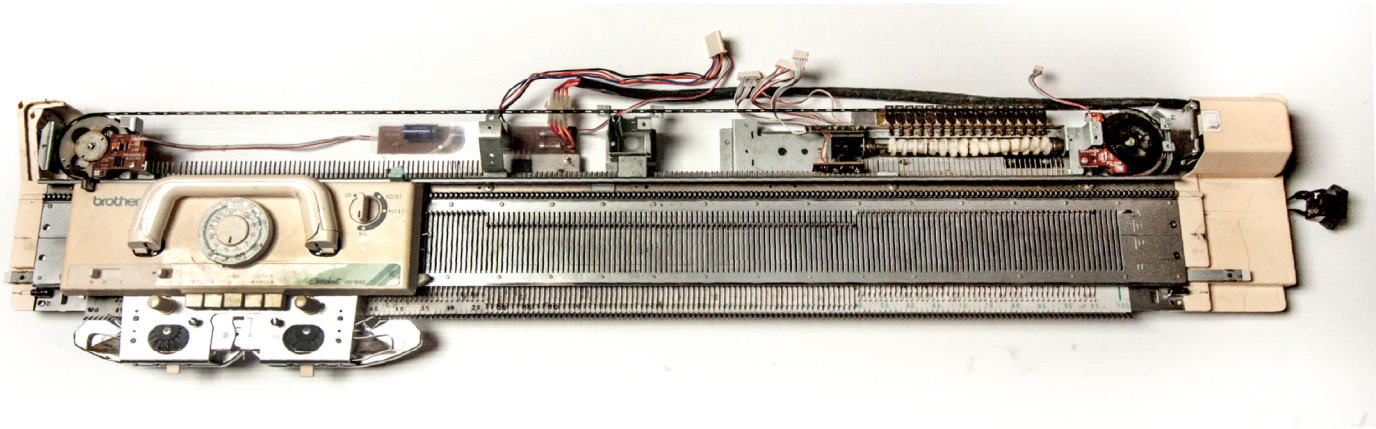
Hi!

So I bought a knitting machine on ebay.

Like one of these:



Mine actually looks like:



It's a Brother KH940. It's from the 80s and uses floppy discs to read knitting patterns. But you can hack it to talk to a modern computer.

I'm not going to talk about that here.

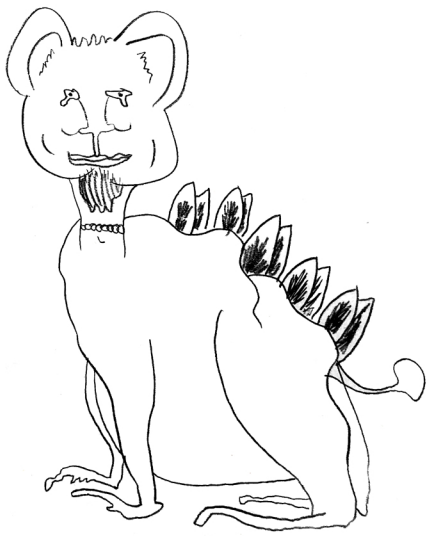
Just google "KH940 hack"
"knitting machine hacking"

ETC.

and you will learn how to solder a little thing to control your machine.

This zine is about how the actual <u>machine</u> works, not the firmware and software and beep boops.

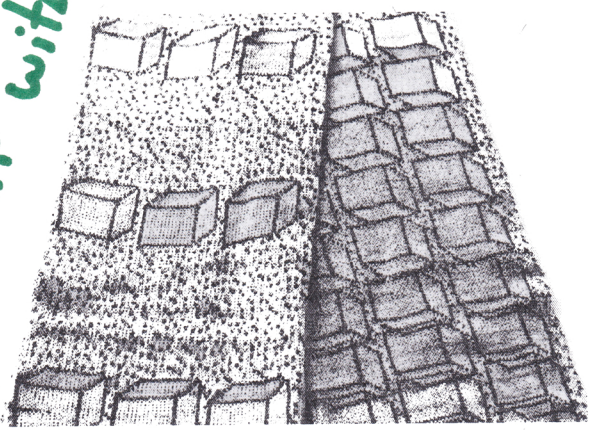
It's also not about how to USE the machine, there are lots of good resources for machine knitting online and also the KH940 has a GOOD user manual (google it! ☺)



I made stuff like this with it:

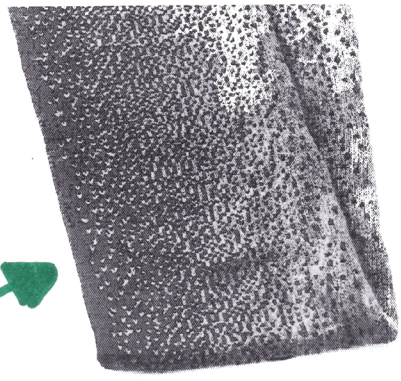
A sweater with my screaming face

A scarf with some cubes



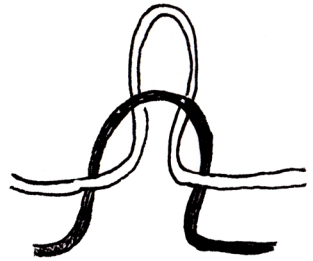
A scaf about anxiety

Aaaand a scarf with a fun gradient on it



(I made a lot of scarves)

ANYHOW!

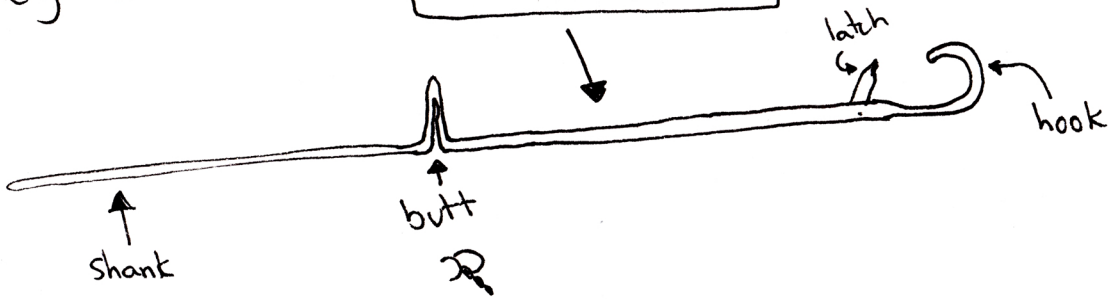


do this a zillion times to get a sweater

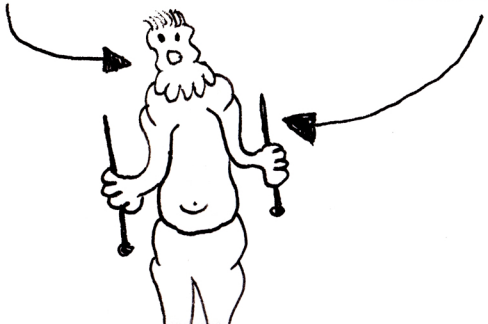
Here's how my knitting machine works in annoying detail.

Knitting machines pull loops of yarn through other loops of yarn.

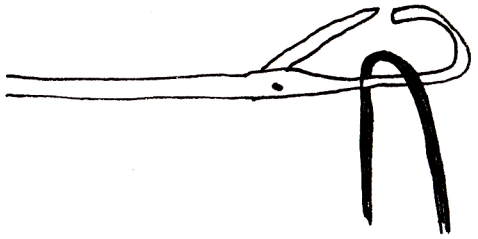
They do it with latch needles. (or mine does)



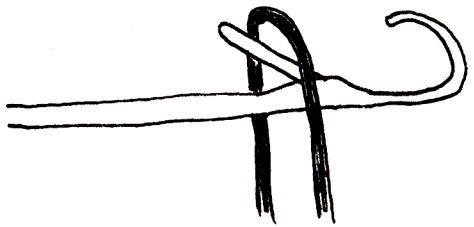
PEOPLE do it with knitting needles, but the result is the same.



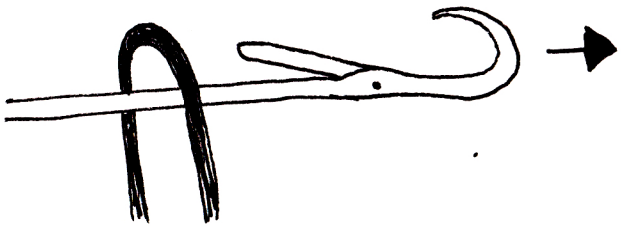
Here's how the latch needles do it.

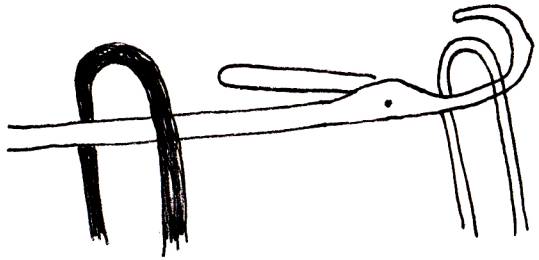
① 

Start with one loop in the hook, latch closed.

② 

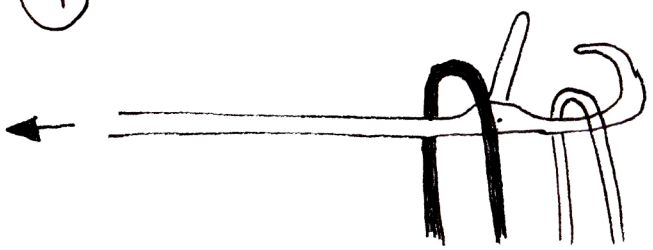
Move the needle forward to slip the loop over the latch.



③ 

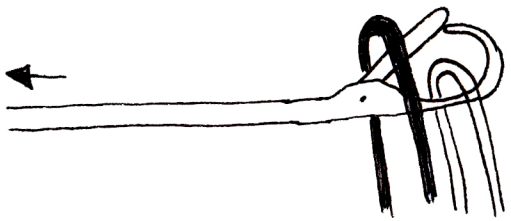
Put a new loop on the latch.

4

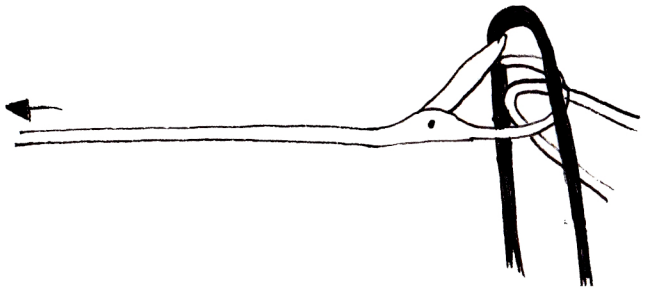


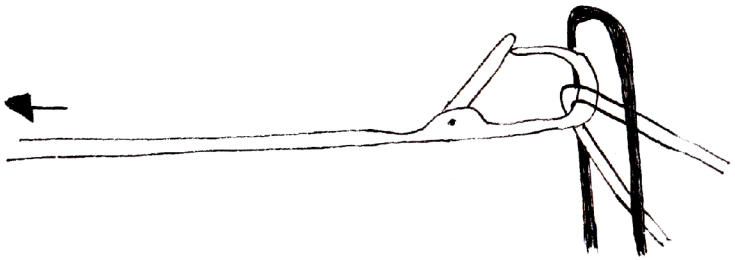
Pull the needle back, forcing the old loop over the latch.

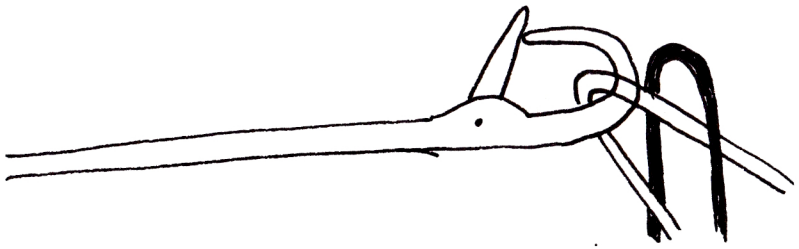
5



Keep pulling the needle back, slipping the new loop through the old loop.



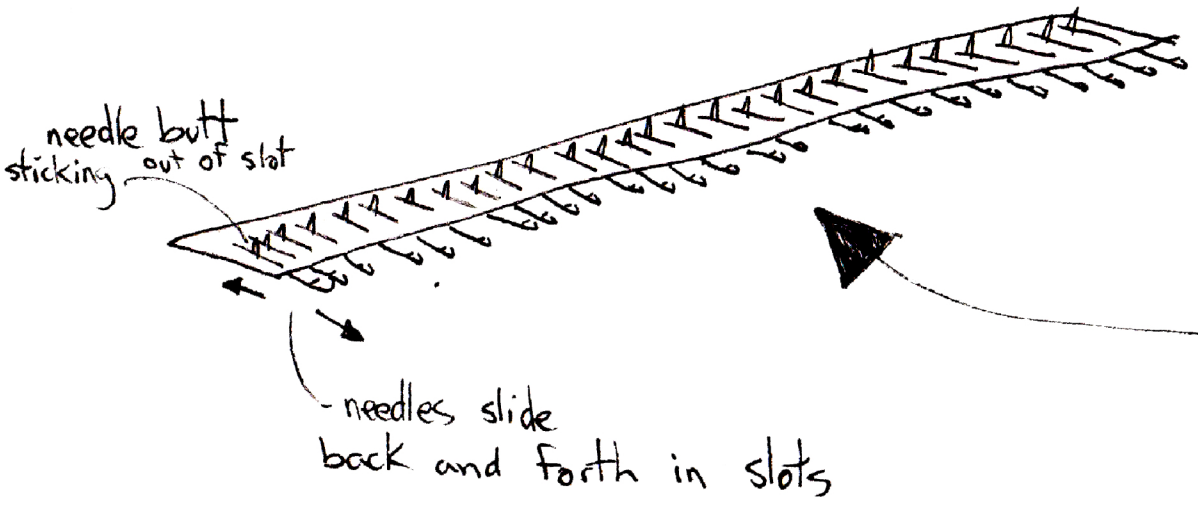




There ya go! Loops in loops.

NOW we just have to push dozens of needles like that really fast.

So we take a bunch of needles and put them in slots in a big metal plate. This way they can slide back and forth.

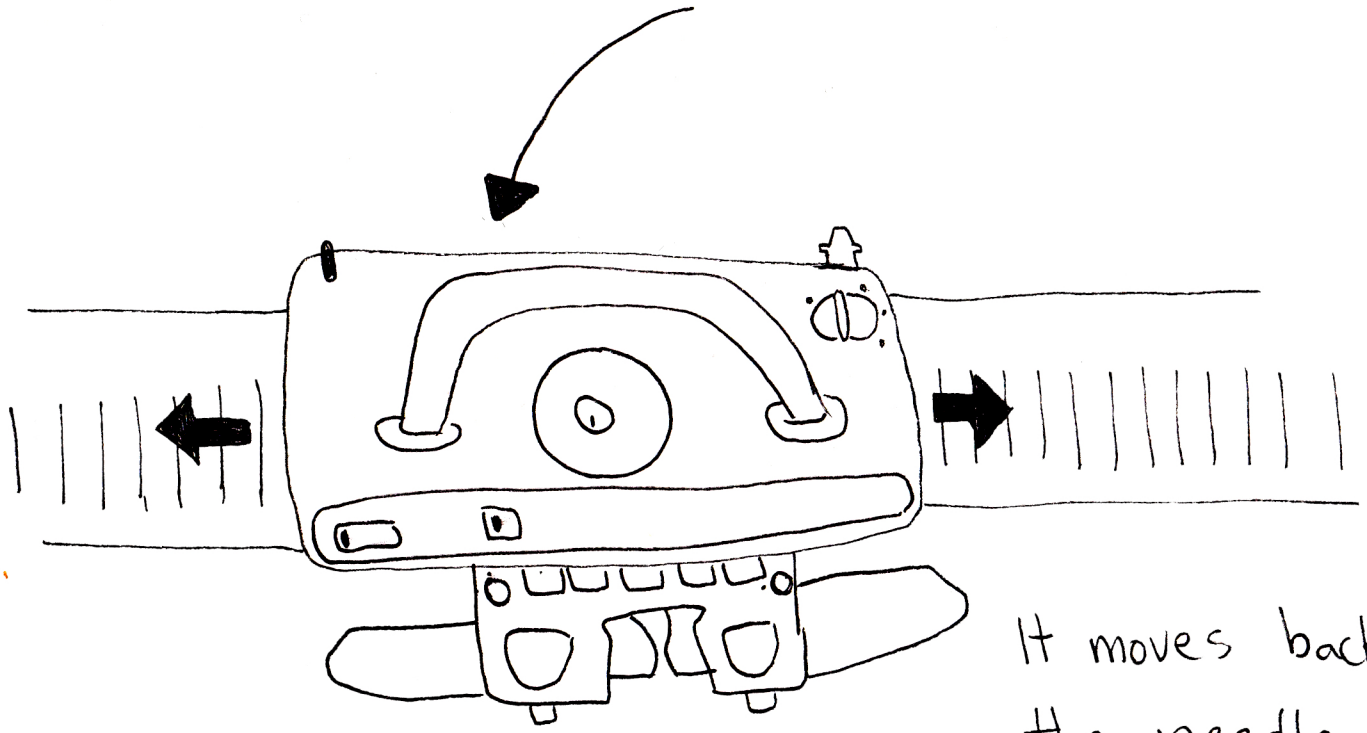


This is called the

needle bed.

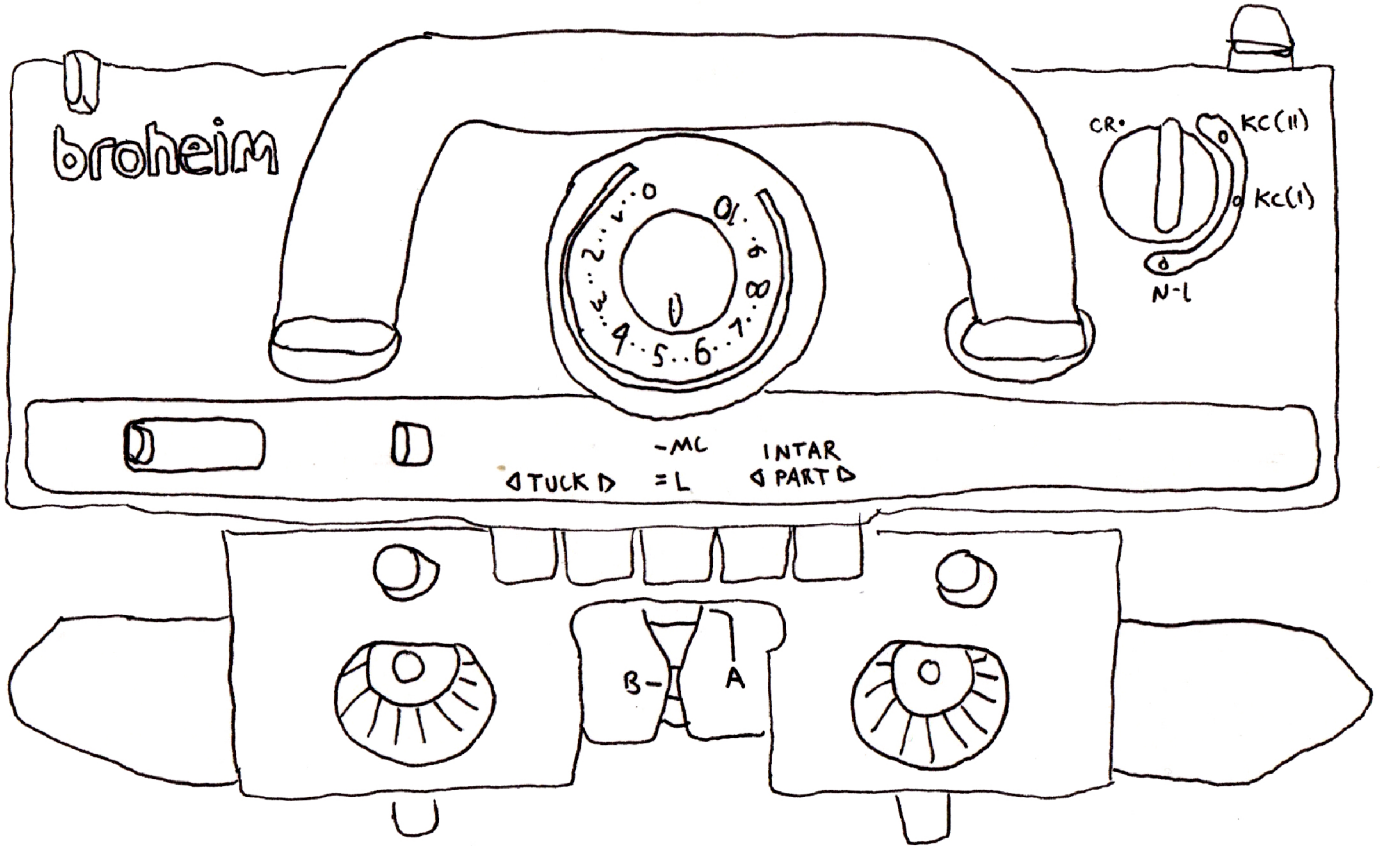
Now we need something to push them back and forth.

That's what the carriage is for.

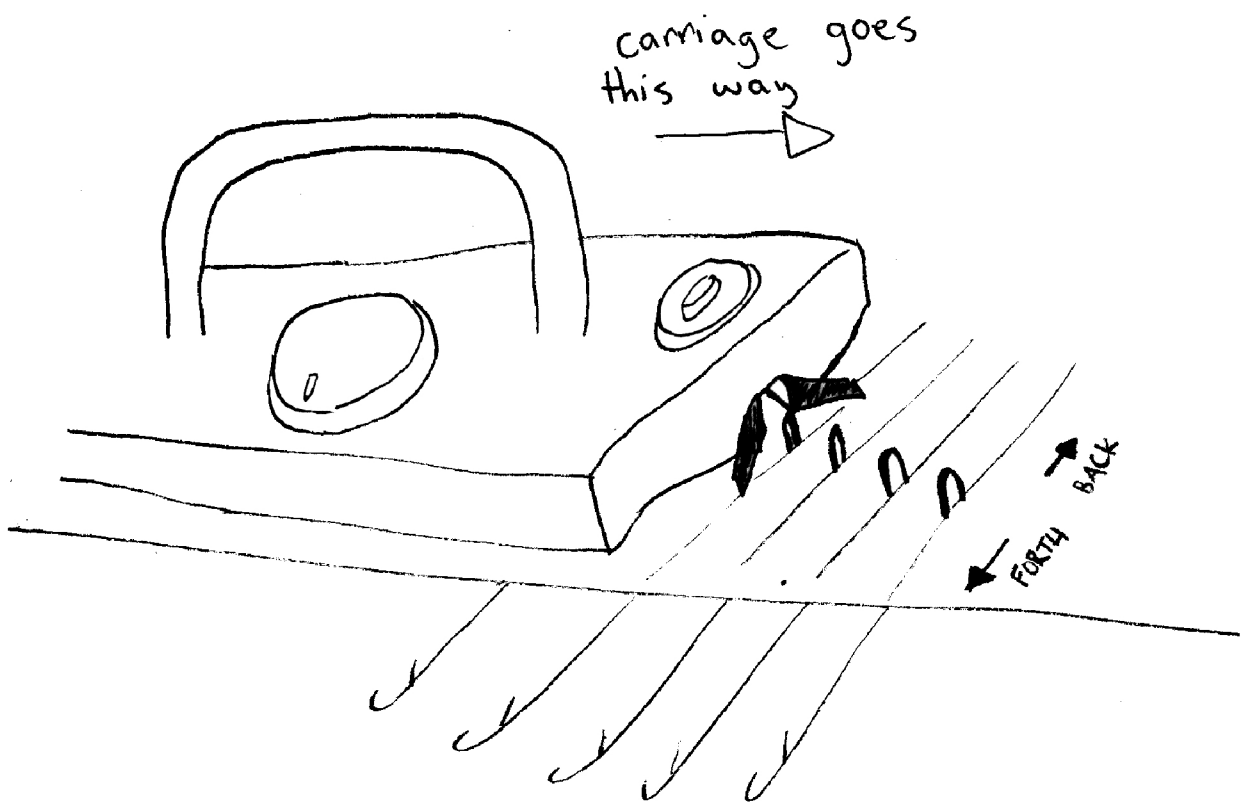


It moves back and forth along the needle bed.

The Carriage

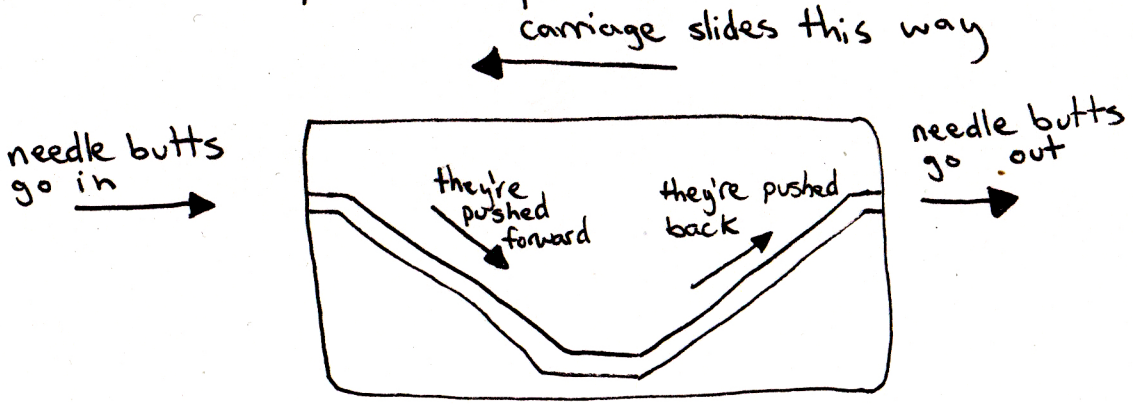


The carriage has channels on its underside that push the needle butts back and forth.



If we flip it over we can look at the channels.

A simple example would be



(underside of carriage)

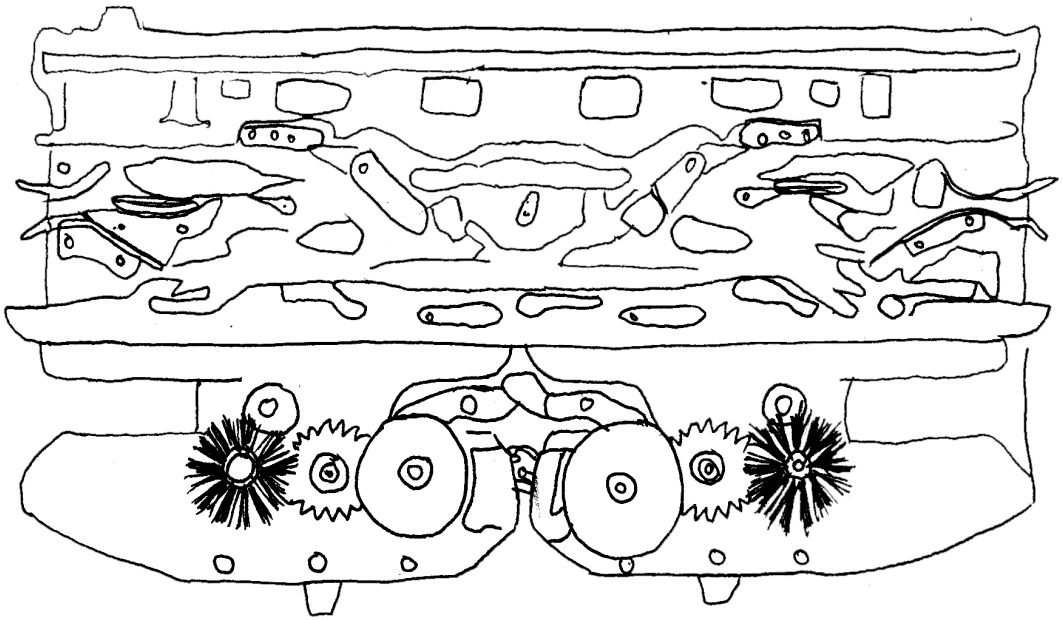
This pushes the needle butts back and forth.

BUT in reality the channels look like this

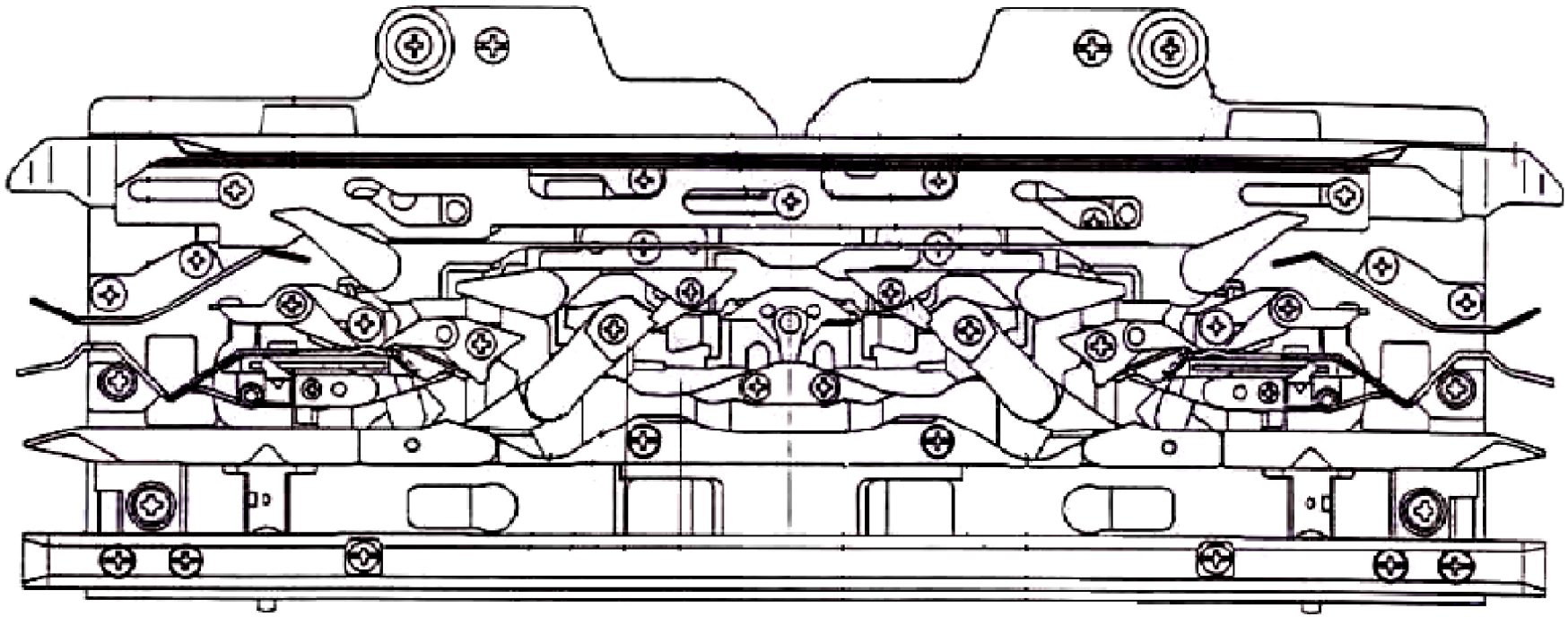
The Carriage Underside

carriage goes this way

needle butts go in



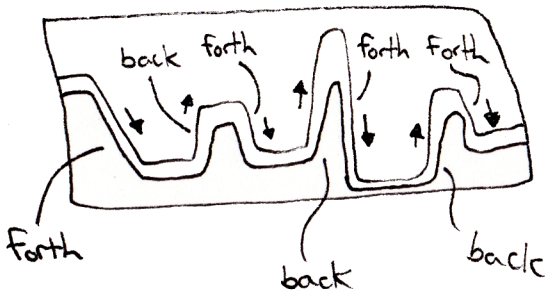
needle butts come out



All this stuff is connected to the knobs and buttons on top of the carriage. It lets you make the stitches bigger or smaller and some other fancy stuff.

BUT the basic idea is the same.

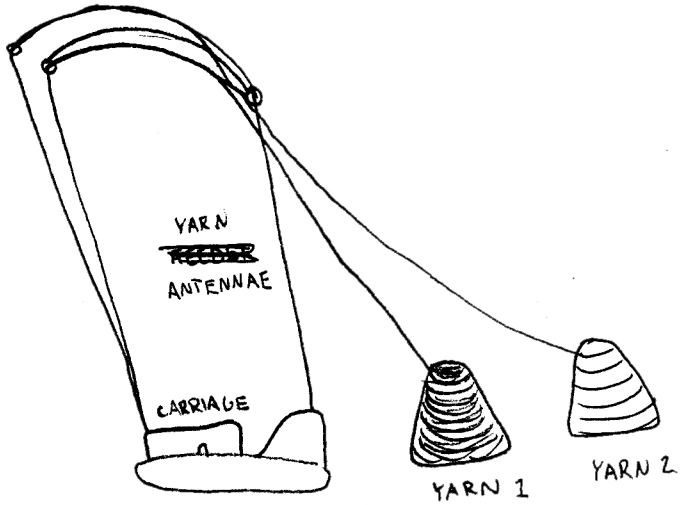
like, you could have a channel like this



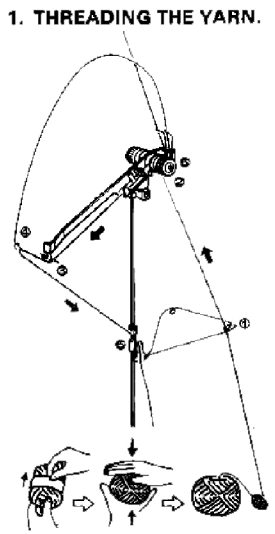
a weird carriage.

you could make the needles go back and forth any which way! But it wouldn't knit very well!

The other thing the carriage does is bring yarn to the needles.



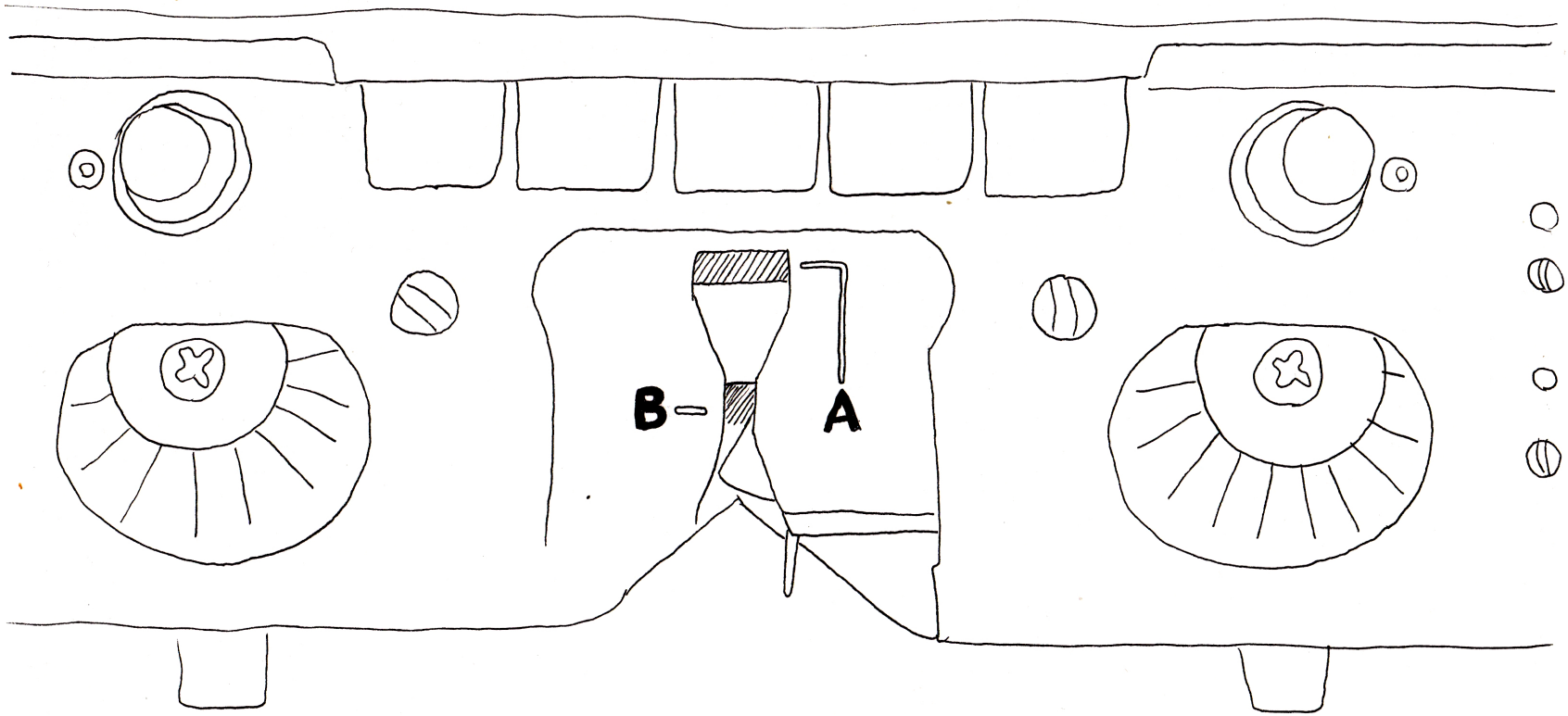
SIDE VIEW

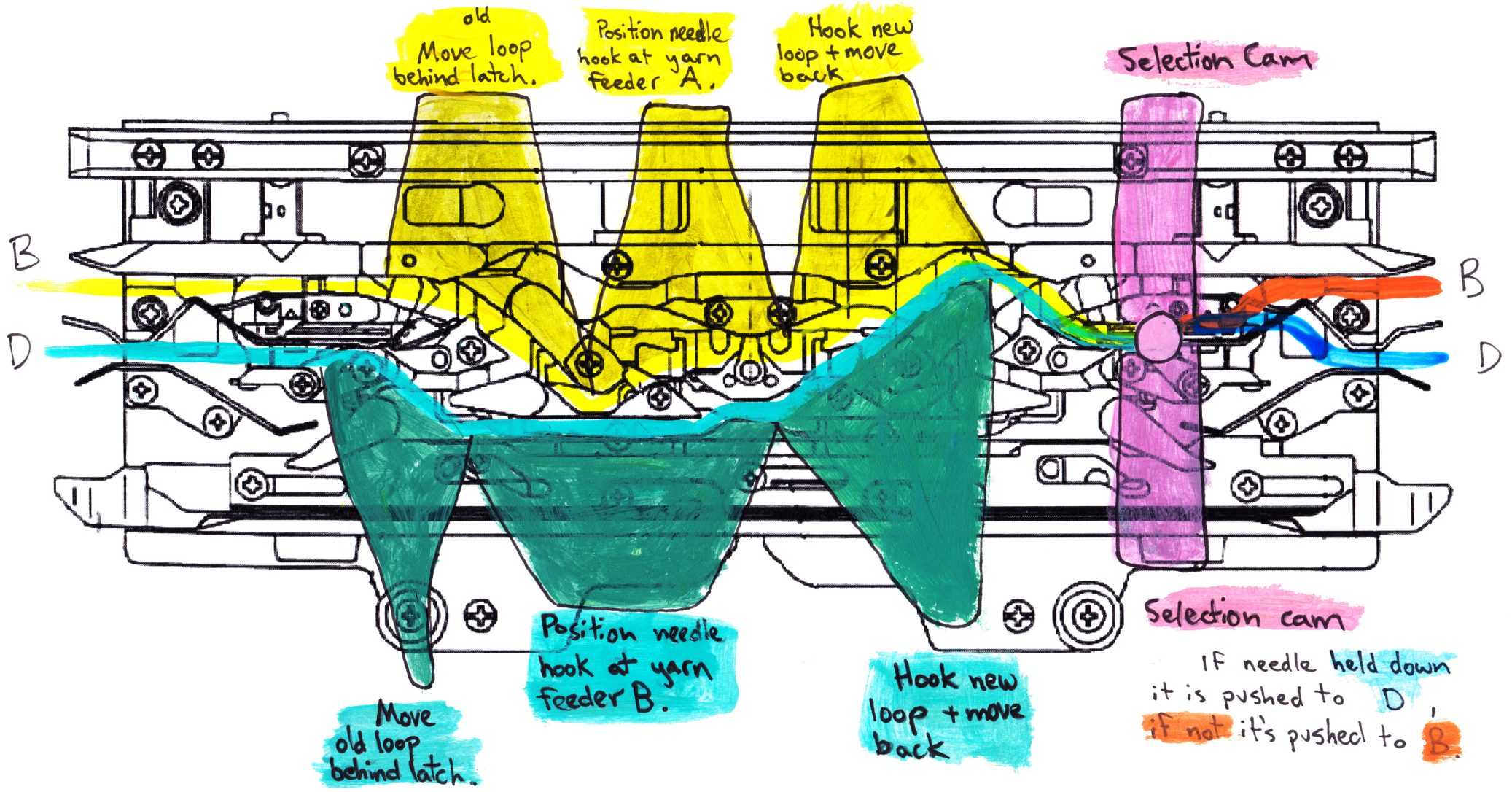


The yarn goes thru an antenna thing so that it has a consistent tension going into the carriage.

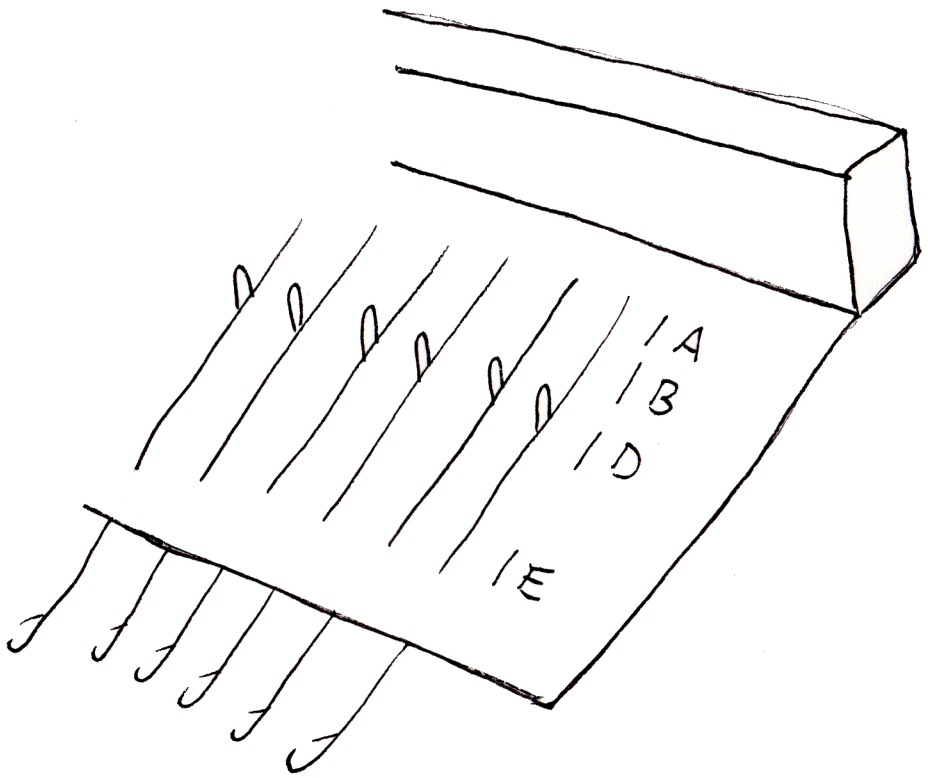
So if we push some needles to position A and some to B, we can knit in two different colour yarns!!!!

Yarn feeders A and B.




old
Move loop behind latch.
Position needle hook at yarn feeder A.
Hook new loop + move back
Selection Cam
B
D
B
D
Move old loop behind latch.
Position needle hook at yarn feeder B.
Hook new loop + move back
Selection cam
If needle held down it is pushed to D,
if not it's pushed to B.
Direction of carriage
Direction of needle butts thru carriage

There are 4 positions the needle butts can be pushed to.

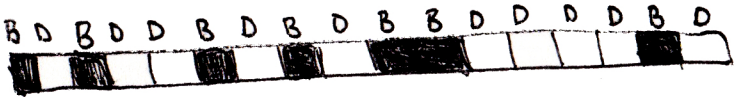


When needles enter at B position they grab yarn from feeder A.

When they enter at D position they grab yarn from feeder B.

SO we just need to push the needles to B or D according to the pixels in a row of a 2 colour image!

so, like:



or like:

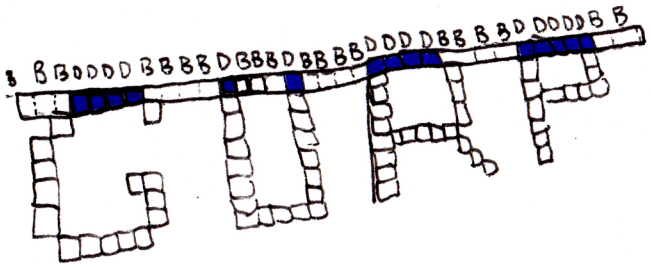


Fig 1. Gurp!

BUT

HOW do we push them to B or D???!!?!?

Position	Name	Description
A	Non-working position (NWP)	The needles pass thru a straight channel at the top of the carriage. This is where you put the needles you don't want to knit with.
B	Working Position (WP)	Needles positioned here will be pushed to yarn feeder A and pulled back.
D	Upper Working Position (UWP)	Needles positioned here will be pushed to yarn feeder B and pulled back.
E	Holding Position	Needles in this position will hold their current loops but not catch and knit new loops until returned to either B or D. This is used for shaping things like sleeves/necklines.

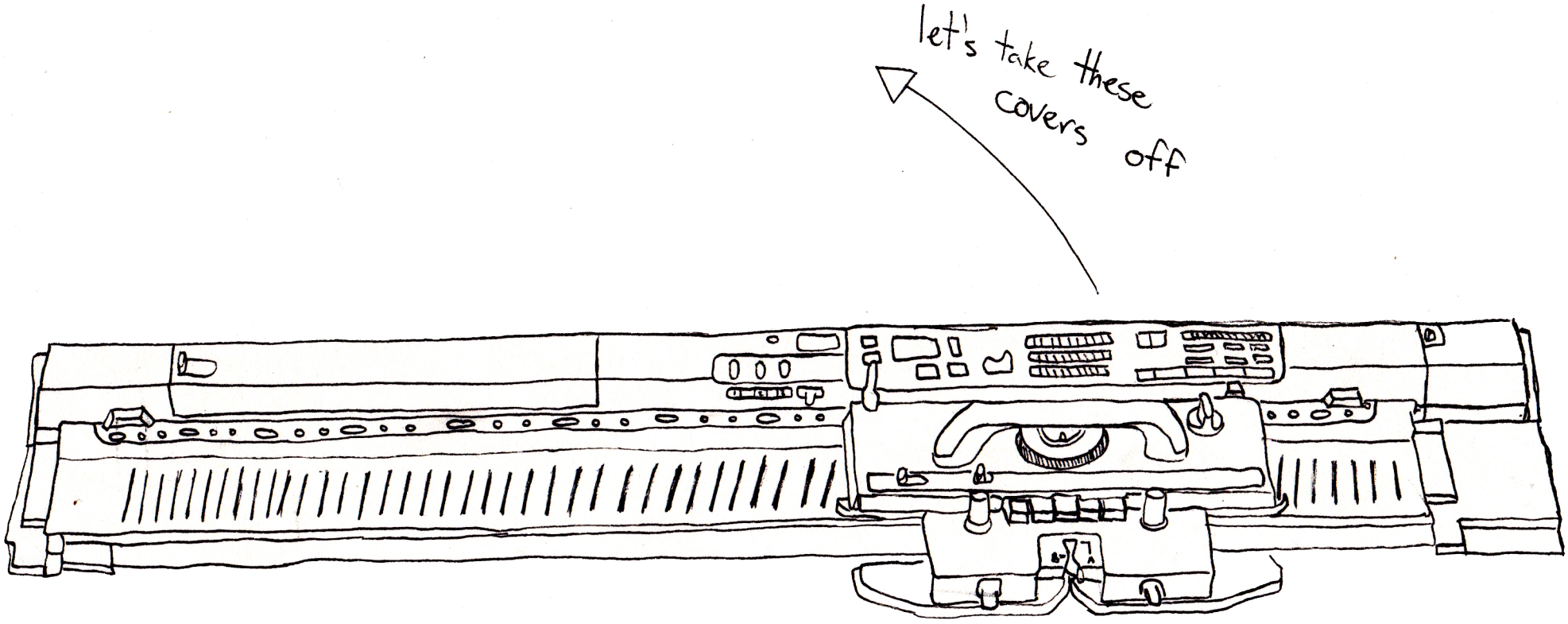
SOoooo, now that we know how the machine forms stitches and picks up different colours of yarn based on the position of the needles (B or D) as they enter the carriage, we can look at how it sets individual needles into those positions according to a pattern.

We gotta do 3 things:

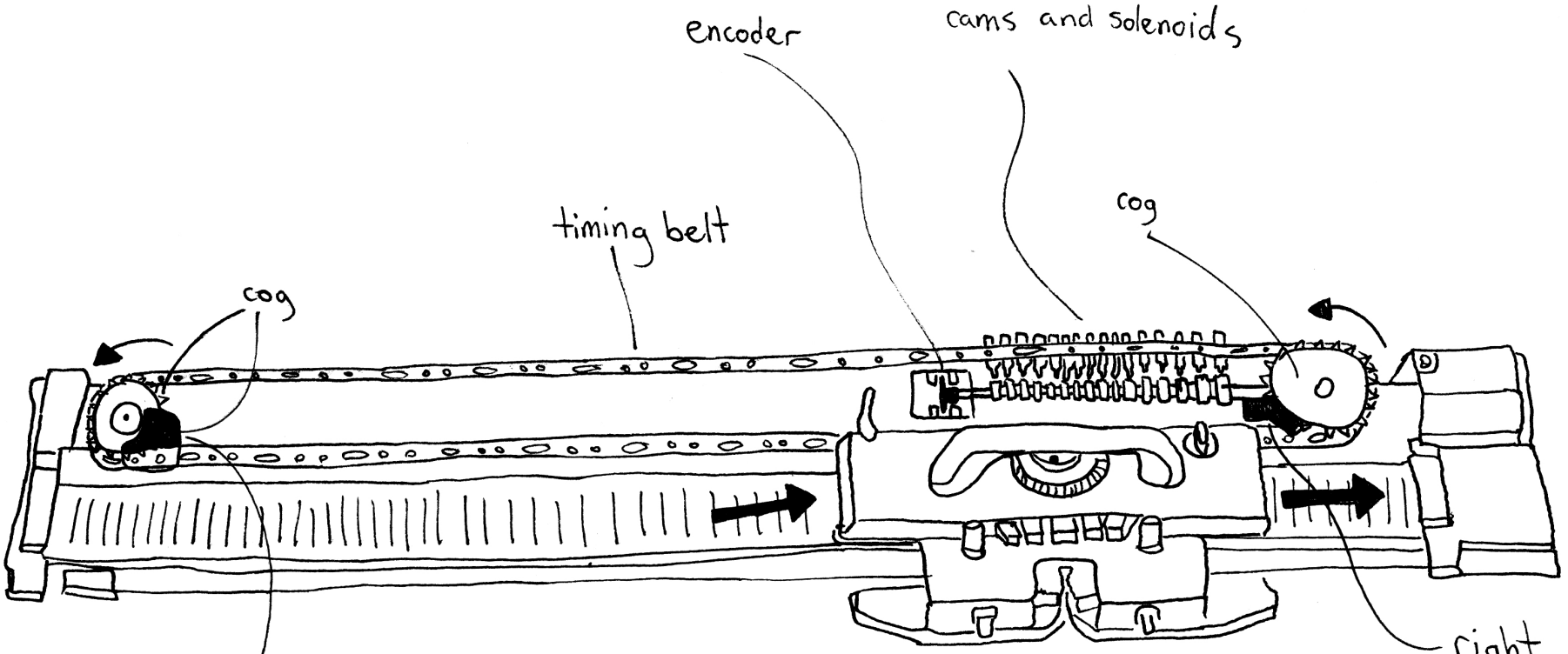
(1) Count needles. Where is the carriage? What needle is it passing over?

(2) Physically address the needle the carriage is passing over.
How do we get at that dang needle?

(3) Push that needle to Position B or D according to the next row in the pattern.

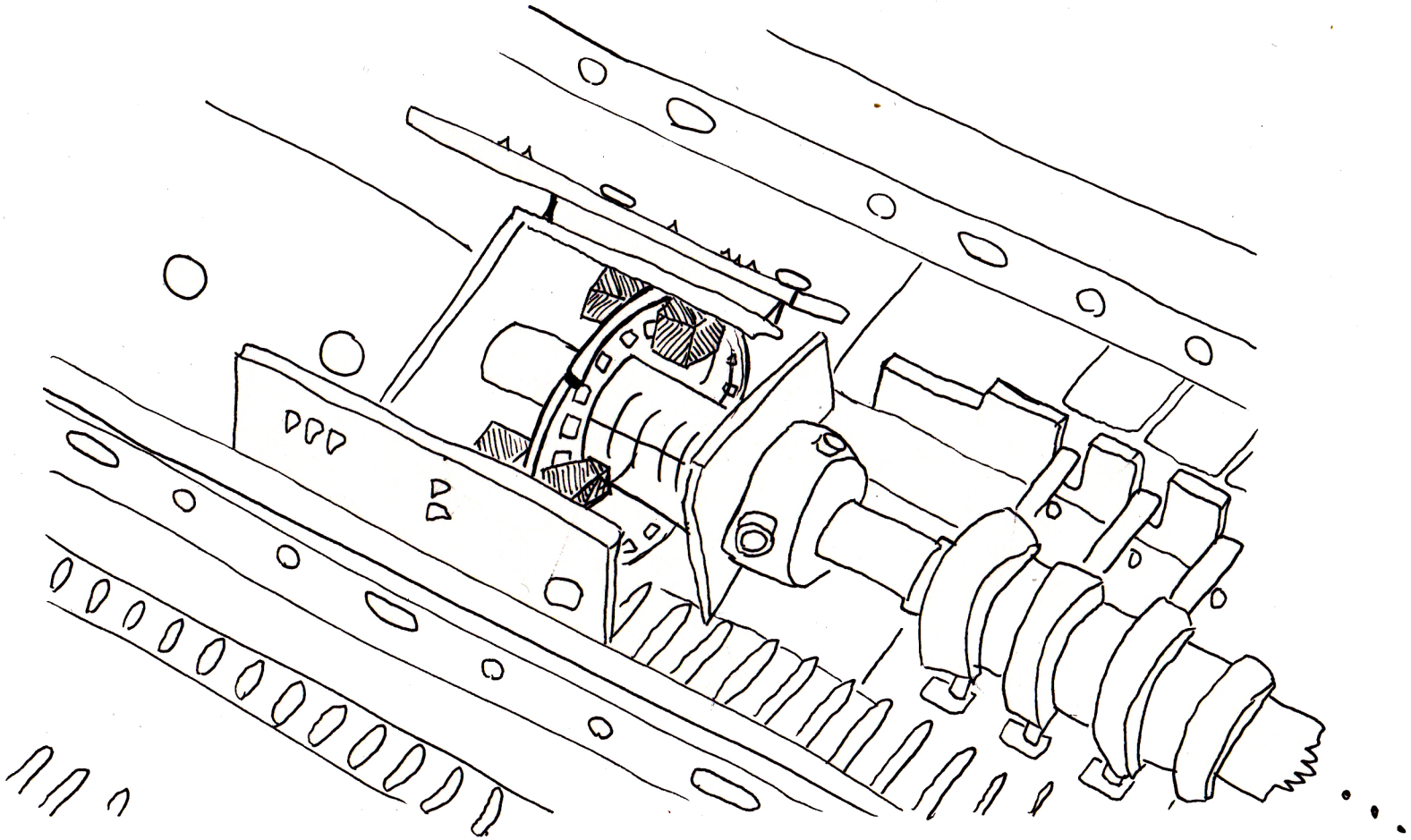

let's take these
covers off

Here's what we see when we remove the covers and the big controller circuit boards:



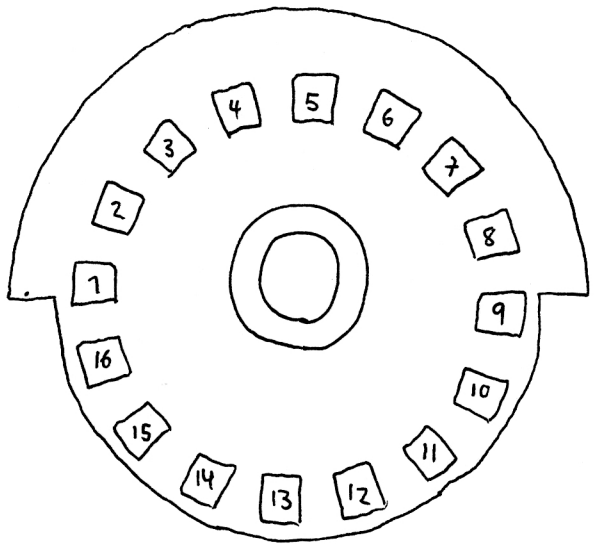
the carriage grabs on to the **timing belt** and moves it, turning a rod with circular **cams** (things that push on stuff) on it AND an **encoder**

This is what the encoder looks like up close.



Basically, it is a disc with holes in it to allow light thru.

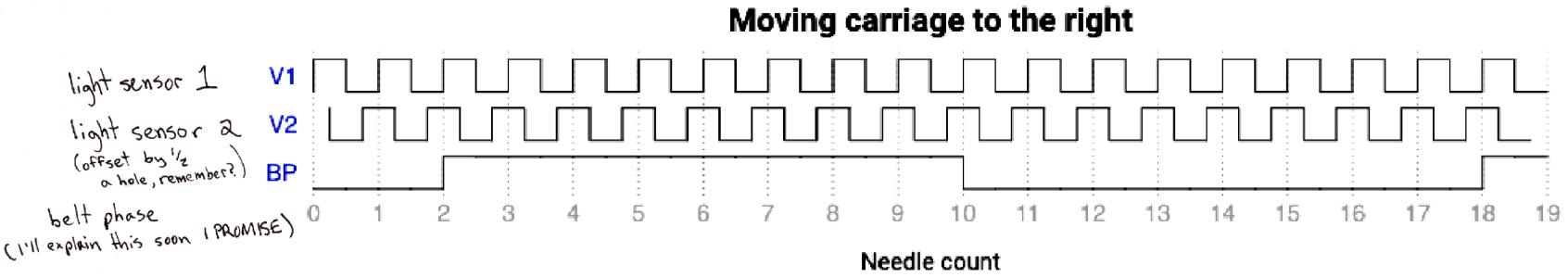
The disc is "pinched" (see prev close-up) by 3 pairs of light sensors that go off when a hole passes them.

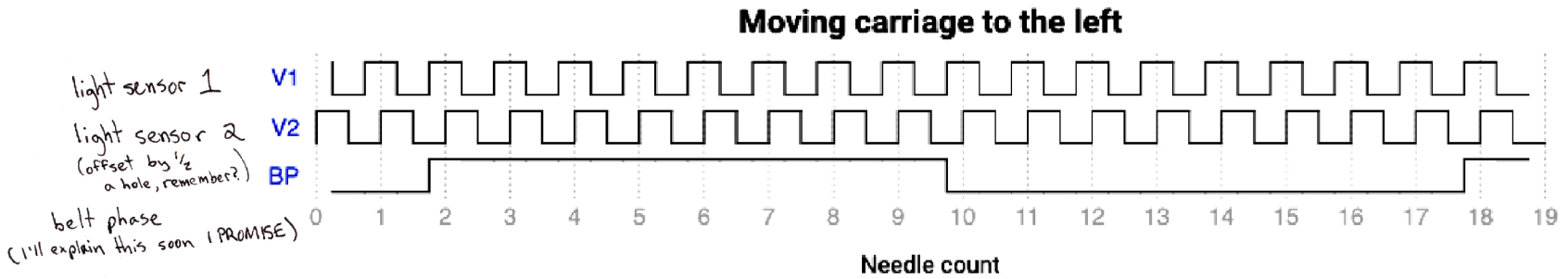


The encoder disc. There are 16 holes and one big tab that spans 8 holes.

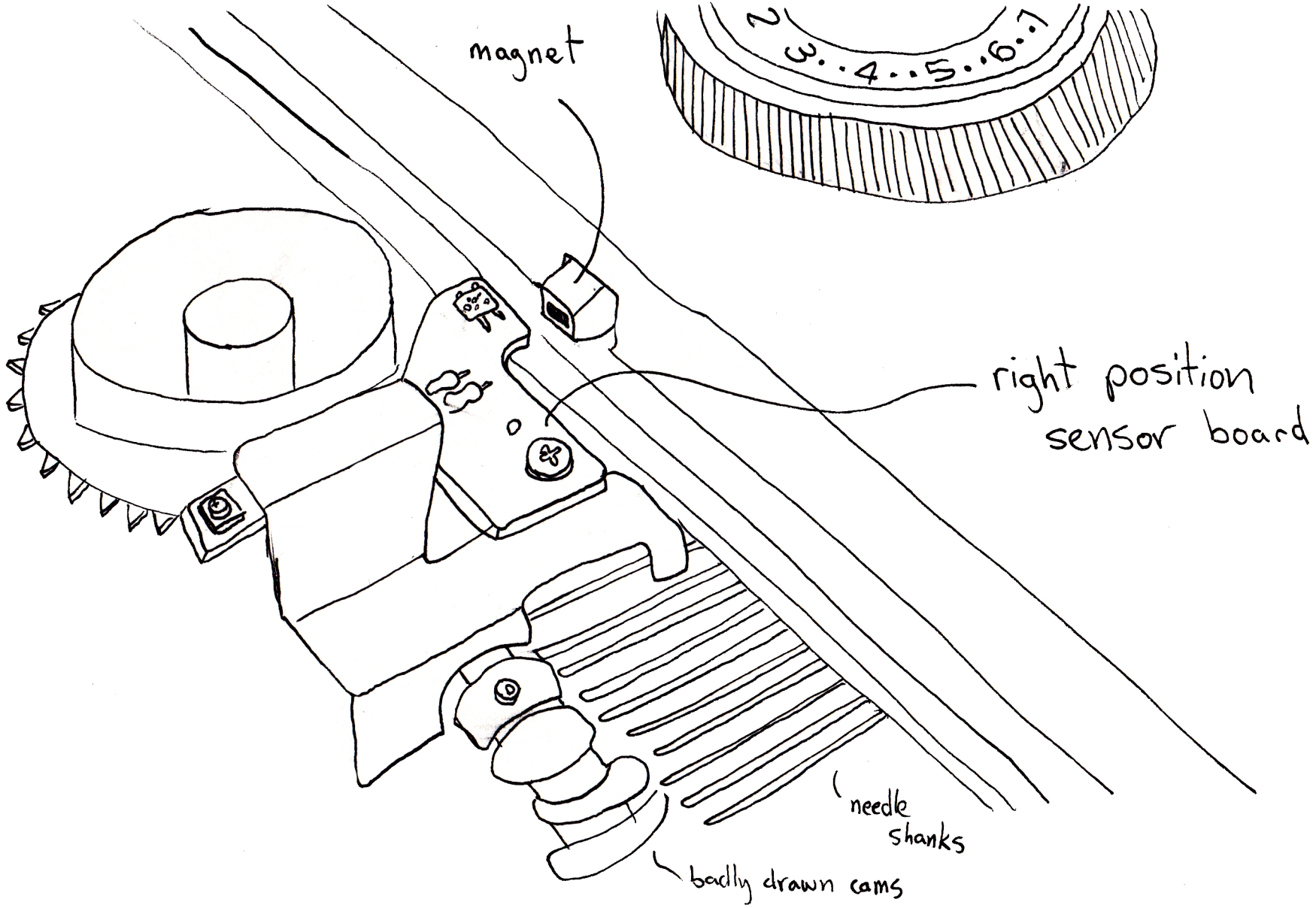
The 16 small holes count individual needles. The tab is for something called BELT PHASE

The small holes are counted using 2 of the light sensors, offset by half a hole. So one light sensor always goes off before the other, depending on the disc's rotation direction. That way, we know if the carriage is going left ⇦ or right ⇨!


Moving carriage to the right
light sensor 1
V1
light sensor 2
(offset by ½ a hole, remember?)
V2
BP
belt phase
(I'll explain this soon I PROMISE)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Needle count

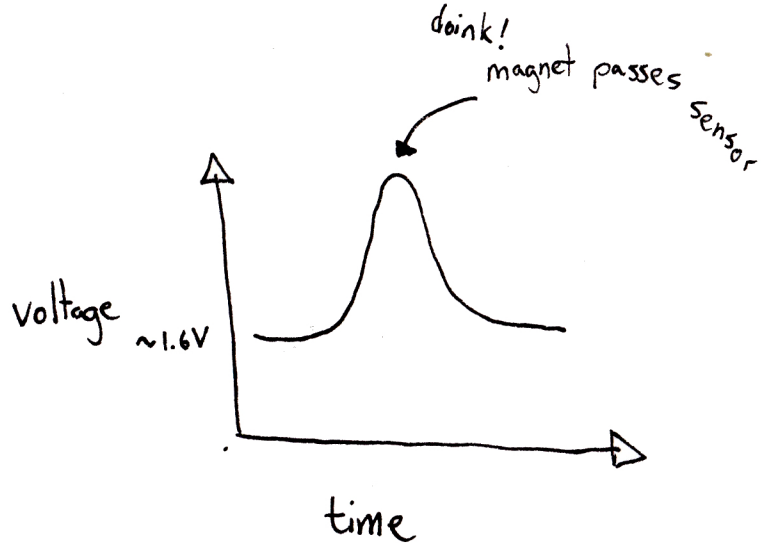

Moving carriage to the left
light sensor 1
V1
light sensor 2
(offset by ½ a hole, remember?)
V2
BP
belt phase
(I'll explain this soon I PROMISE)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Needle count

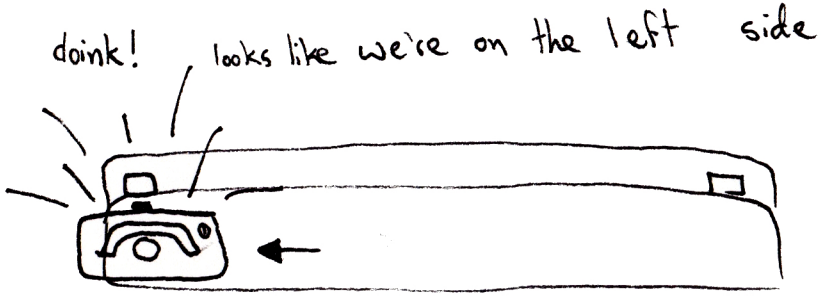
We also need to know where to start counting needles.
That's what the right and left position sensors are for.



There's a magnet on the back of the carriage.

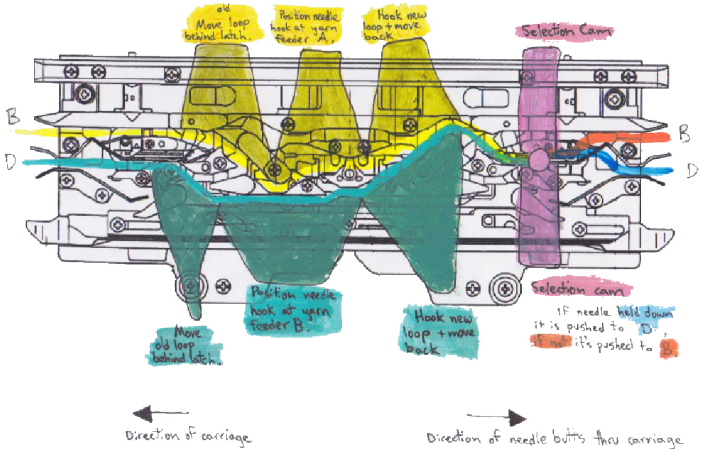
When it passes the position sensors, it sets them off.





How do we actually make a specific needle move back and forth?

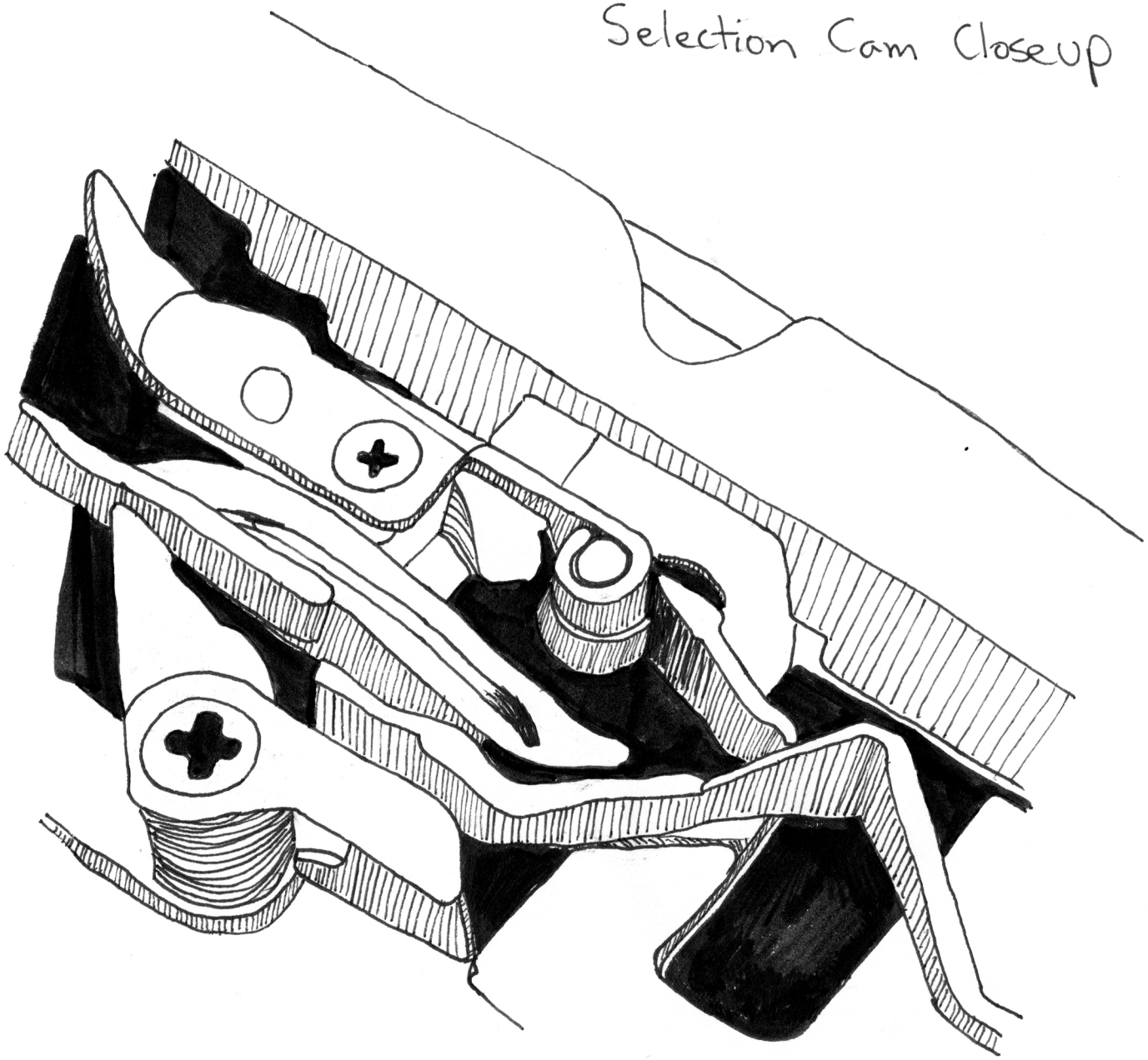
Remember this pic?


Move old loop behind latch.
Position needle hook at yarn feeder "A".
Hook new loop + move back.
Selection Cam
B
D
B
D
Position needle hook at yarn feeder B.
Move old loop behind latch.
Hook new loop + move back.
Selection cam
IF needle held down it is pushed to D
it's pushed to B
Direction of carriage
Direction of needle butts thru carriage

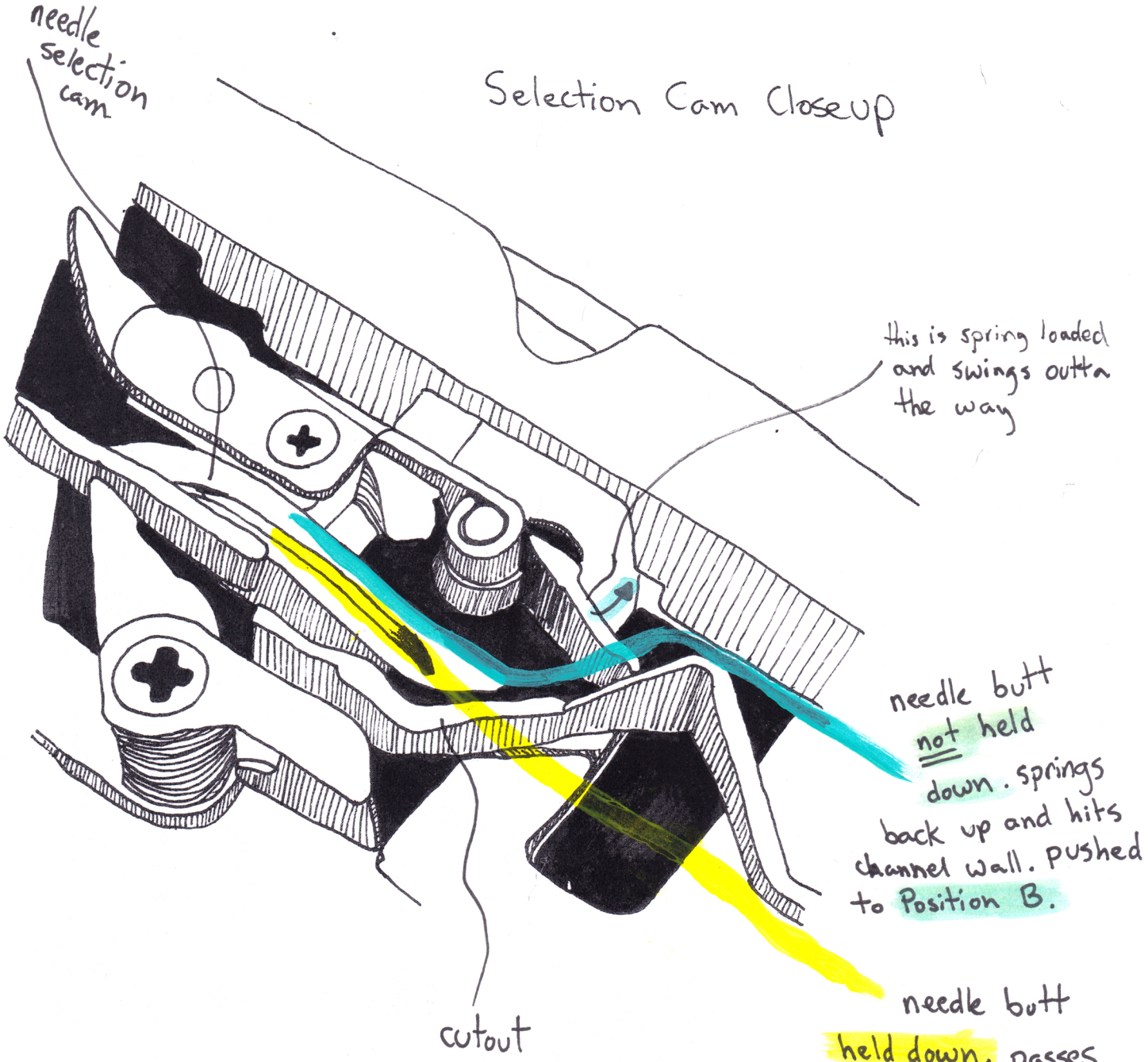
At the part of the carriage labelled "Selection Point" up there is a plastic cam (a hump, basically) that pushes passing needle butts down. The needles are spring-loaded, so they spring back up after they pass this cam.

That is UNLESS while pushed down, something holds them down...

Selection Cam Closeup



Selection Cam Closeup

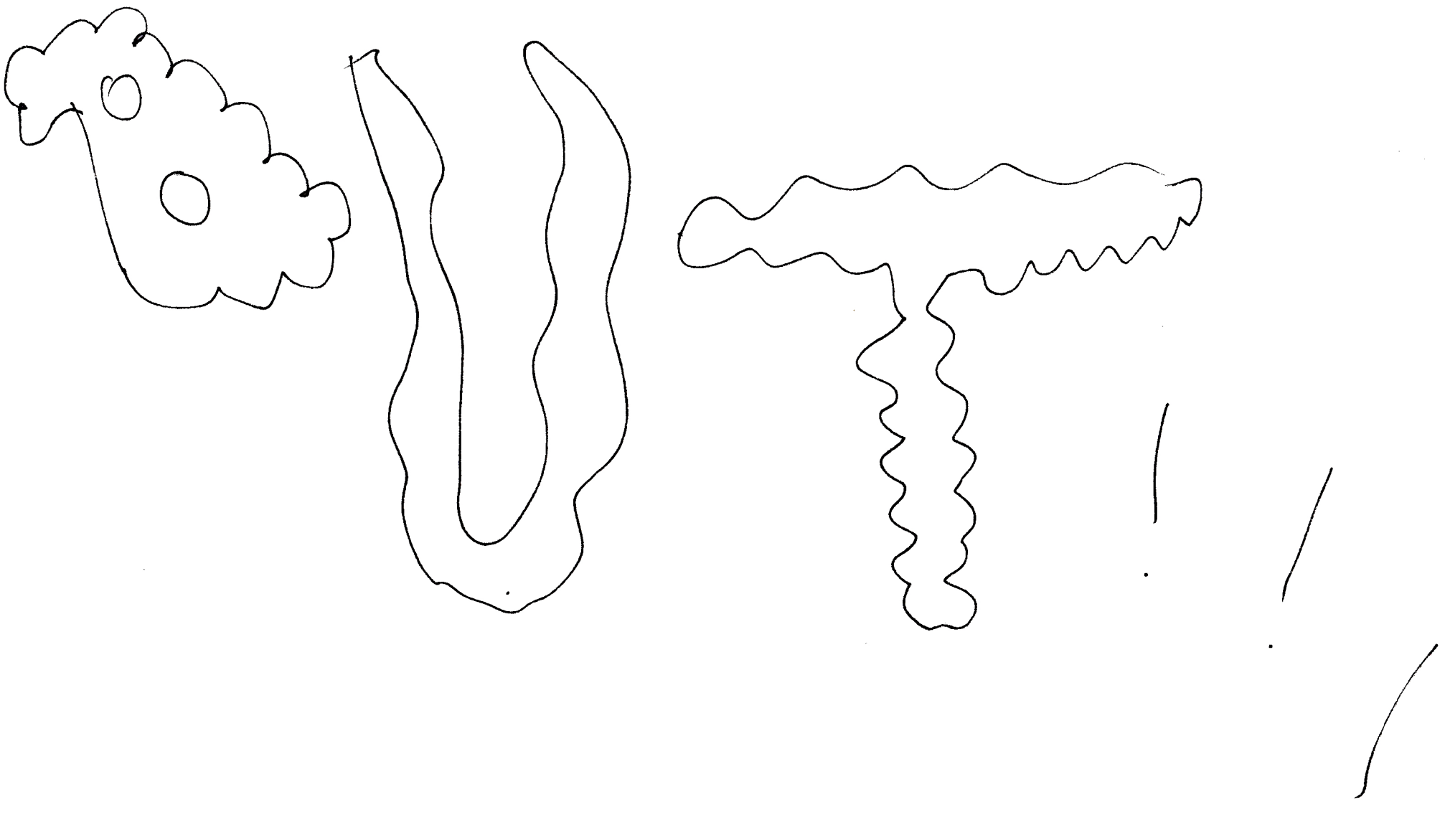

needle selection cam
this is spring loaded and swings outta the way
needle butt not held down. springs back up and hits channel wall. pushed to Position B.
cutout
needle butt held down. passes thru cutout. pushed to Position D.

There's a cutout in the wall of the channel there. See how it gets shorter there?

Needles that are held down will have their needle butts sticking up into the channel LESS, and so will pass thru this cutout and get pushed to Position D.

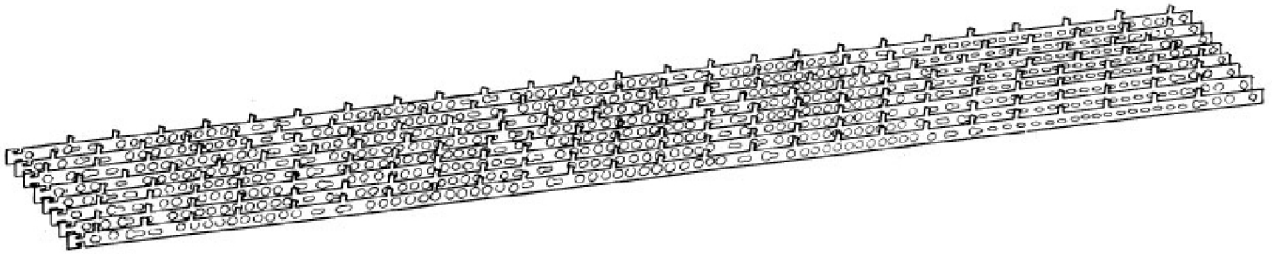
Needles that AREN'T held down will have their butts sticking up MORE and will not pass thru, they will contact the wall of the channel and get pushed to Position B.

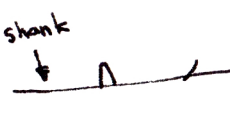
So all we need to do is hold down certain needles at the right time!!!!



HOW do we hold them down?

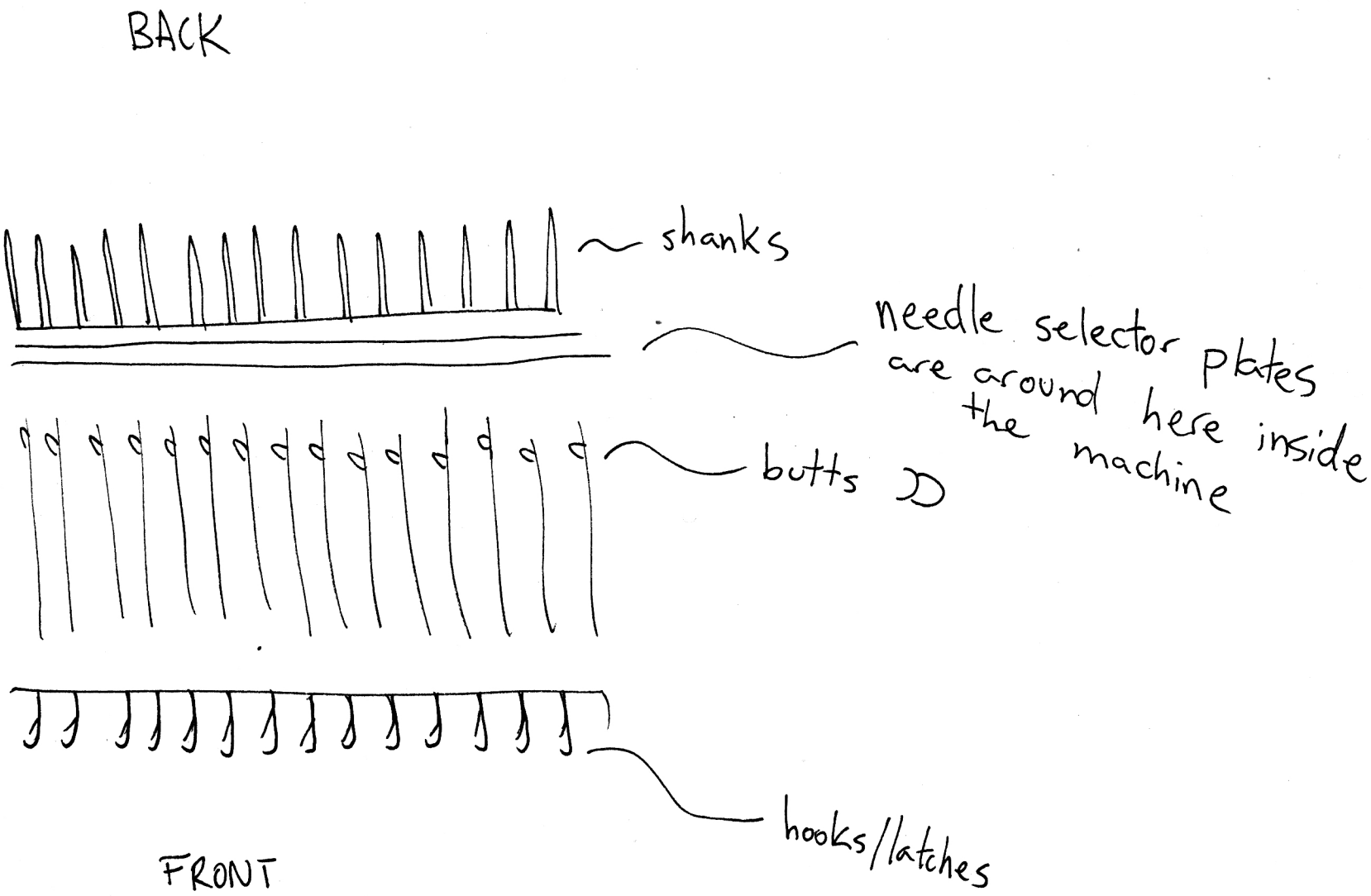
We use the **needle selector plates.**



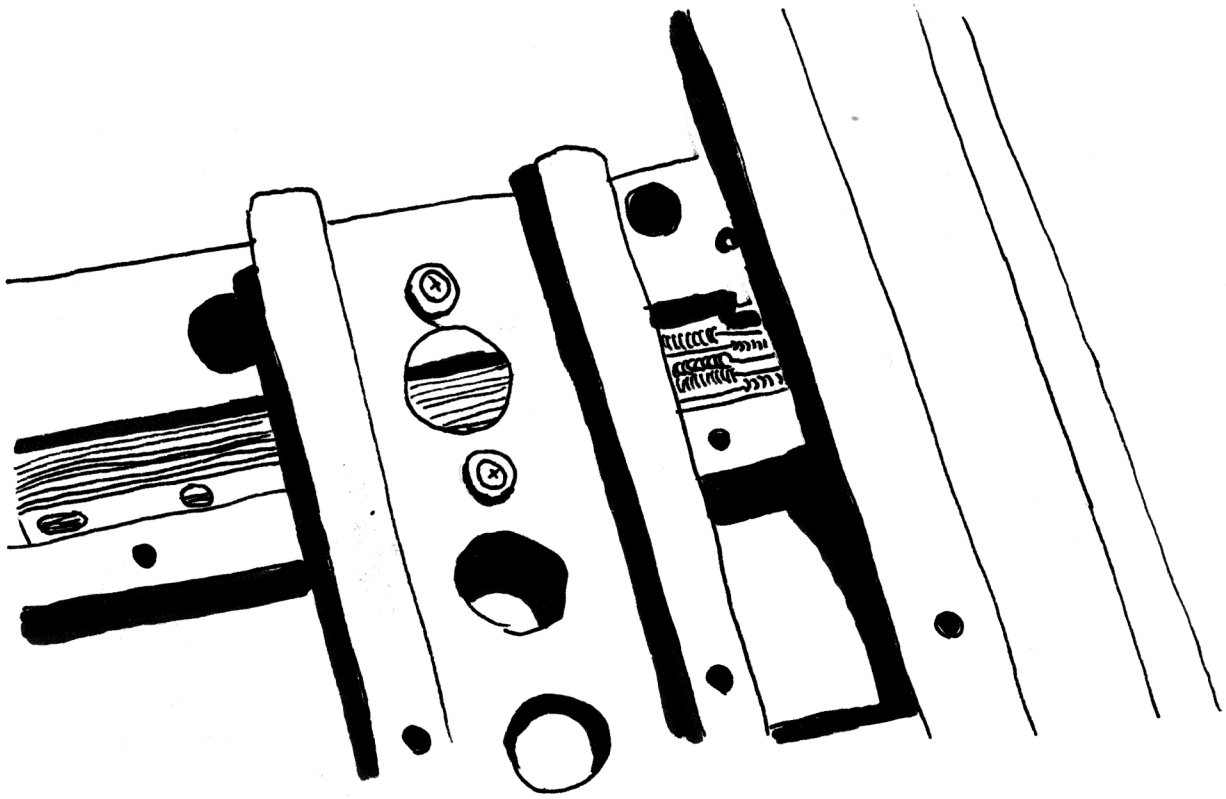
They're these metal strips that sit at the back of the machine near the needle shanks (

).

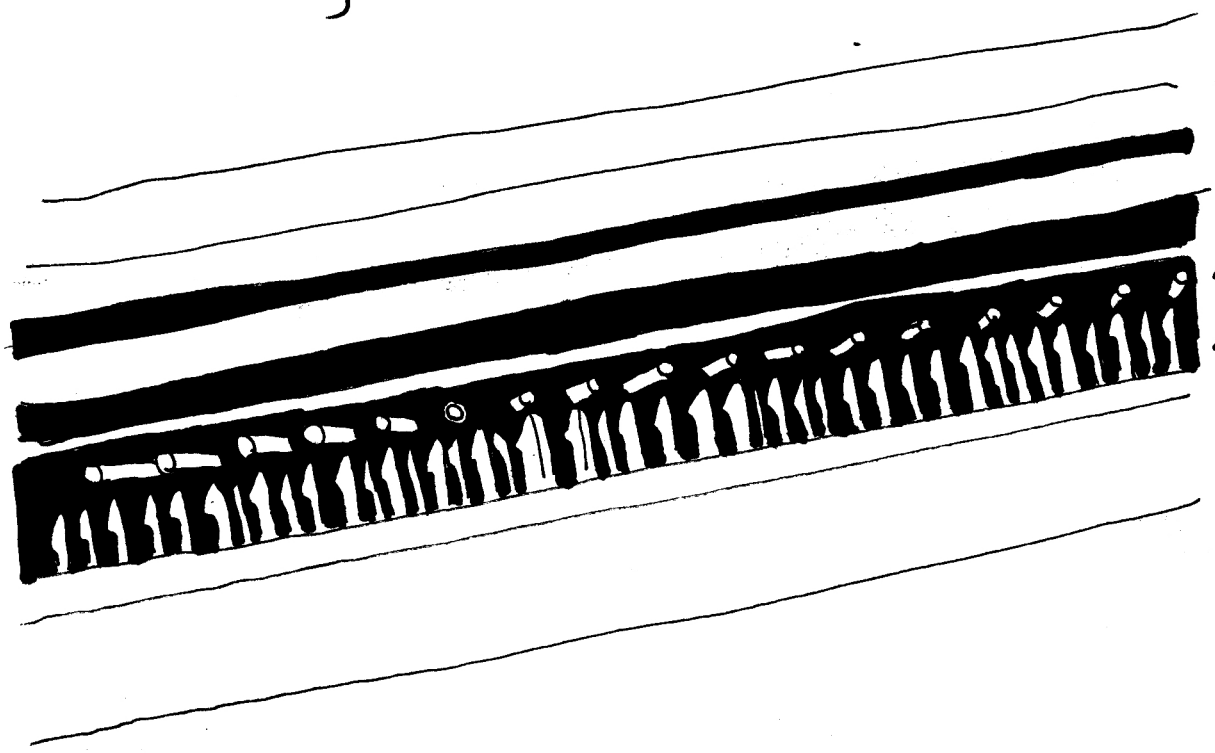
They have tangs on them that can hold the needle shanks down

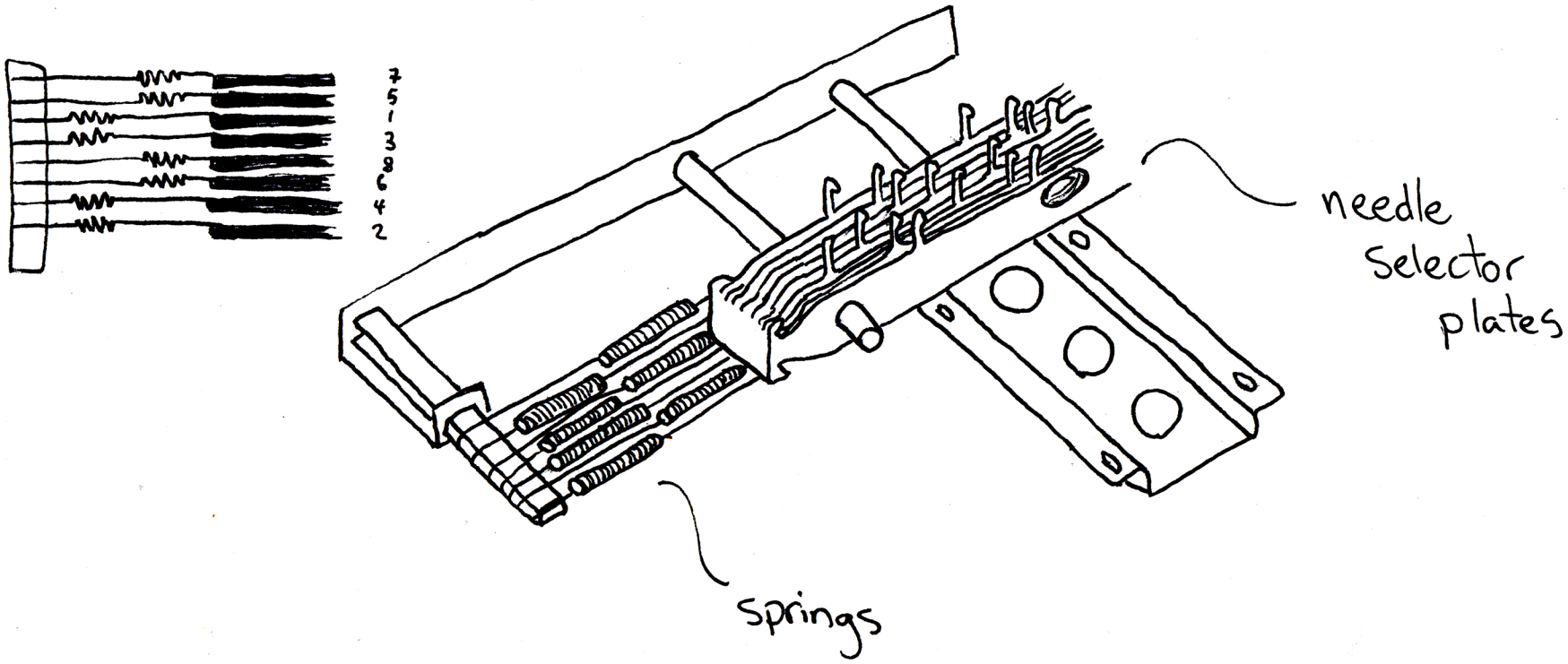

BACK
shanks
needle selector plates are around here inside the machine
butts
hooks/latches
FRONT

If you flip the machine over, you can see the NSPs sandwiched together and attached to the chassis by springs.

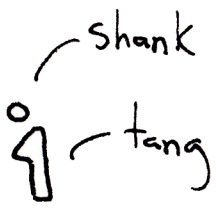


Looking into the back of the machine.

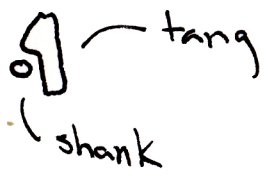



7
5
1
3
8
6
4
2
needle
selector
plates
springs

The needle shanks sit just above these tangs. →

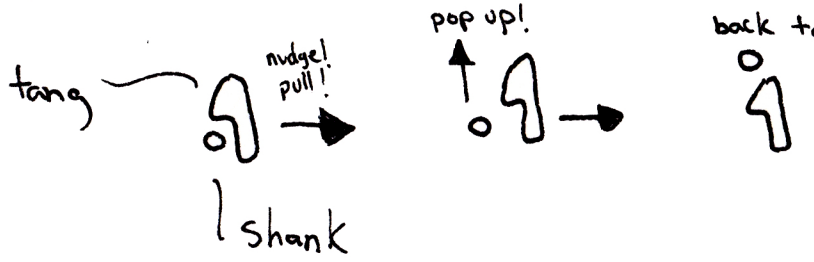


When a needle is pushed down by the needle selection cam, it sinks under the tang. →

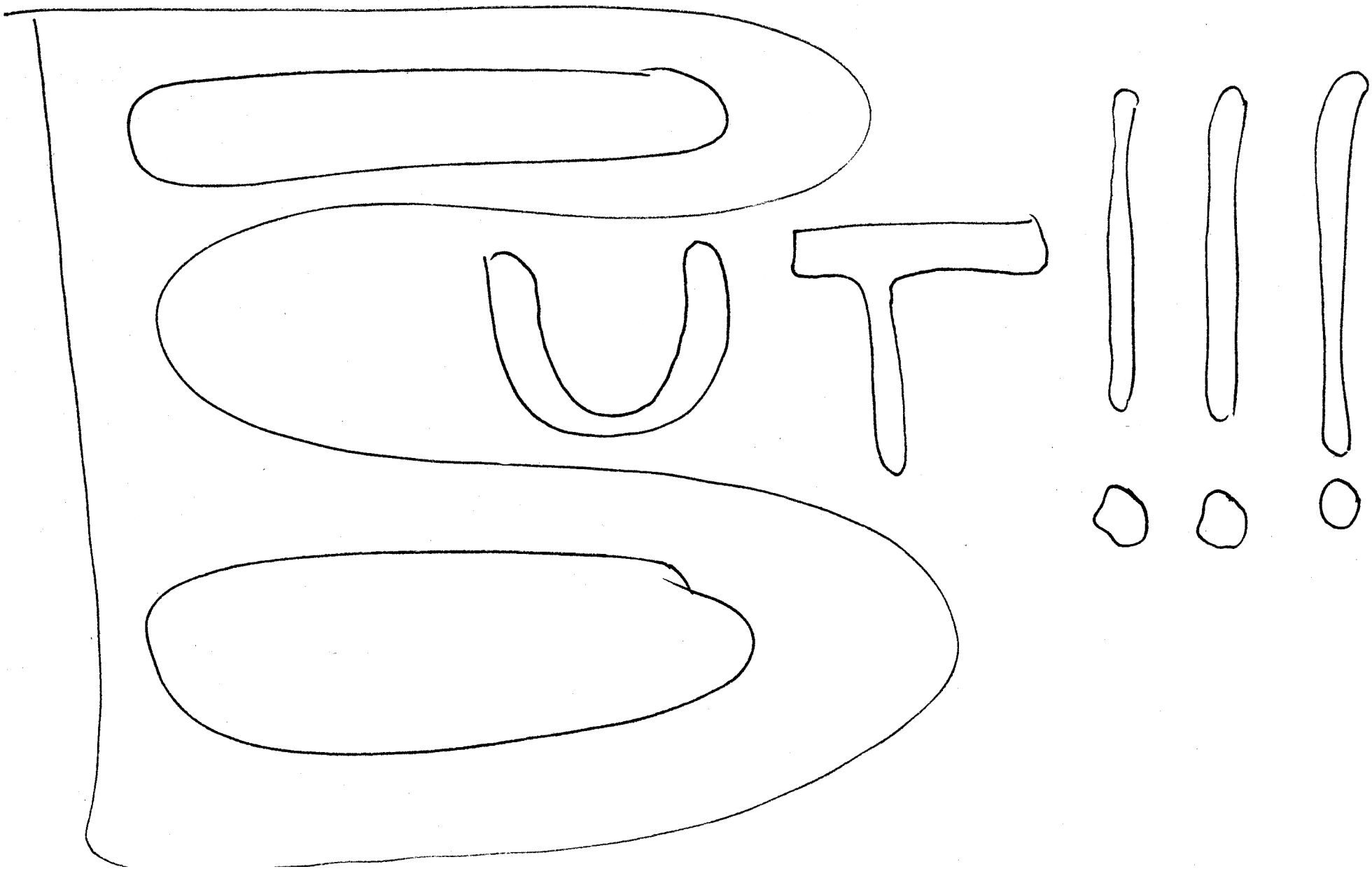


If nothing happens next, the needle stays held down and gets pushed to Position D.

HOWEVER!!! If the needle selector plate attached to the tang is nudged to the side, it will release the shank which will pop up and be pushed to Position B.

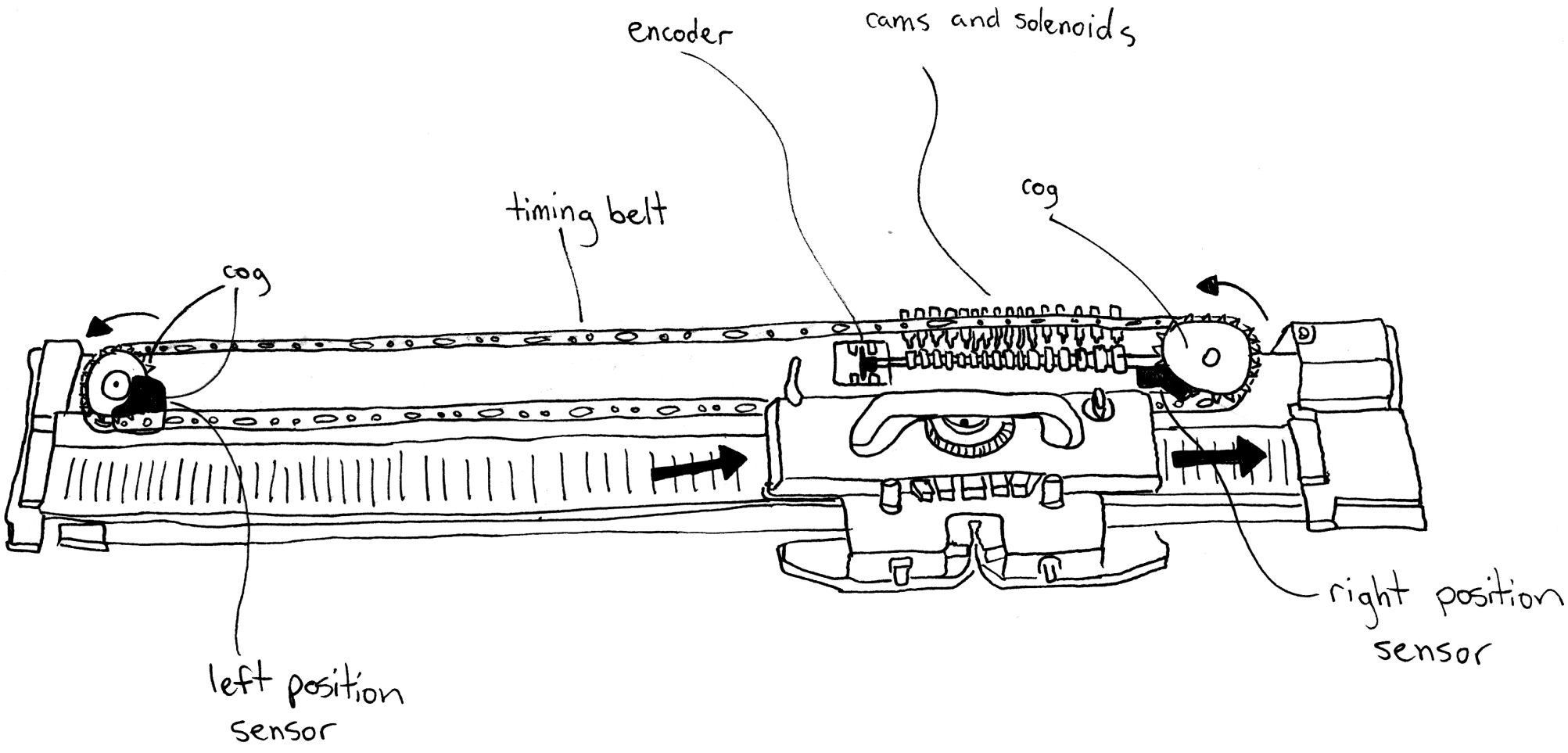


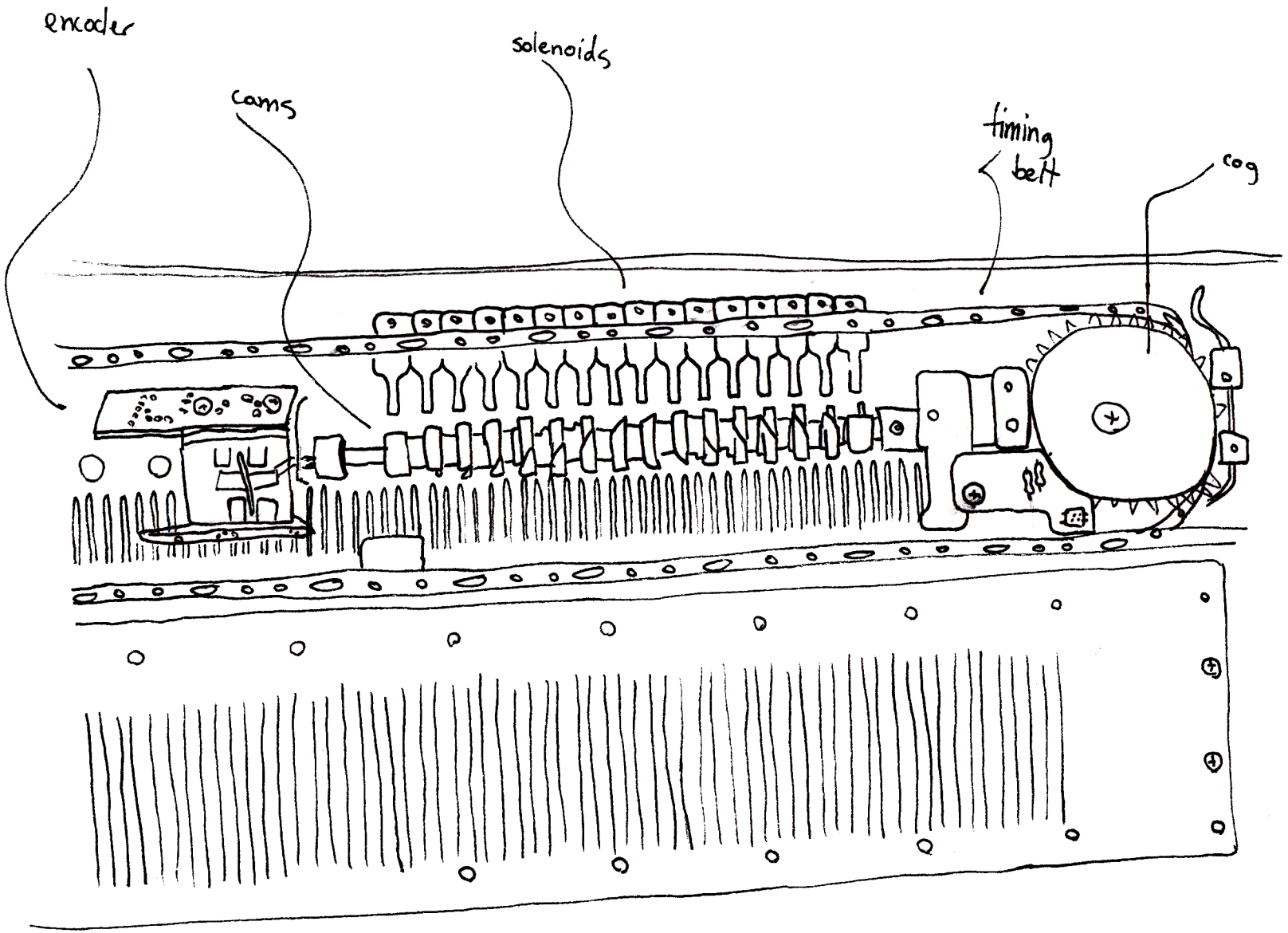
SO, to set the position of a certain needle
we need to pull/nudge the right needle selector plate.



How do we nudge them? And which one do we nudge?

That's where the rotary cams and solenoids come in.

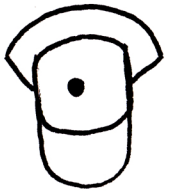



encoder
cams
solenoids
timing belt
cog

timing belt

solenoid armatures

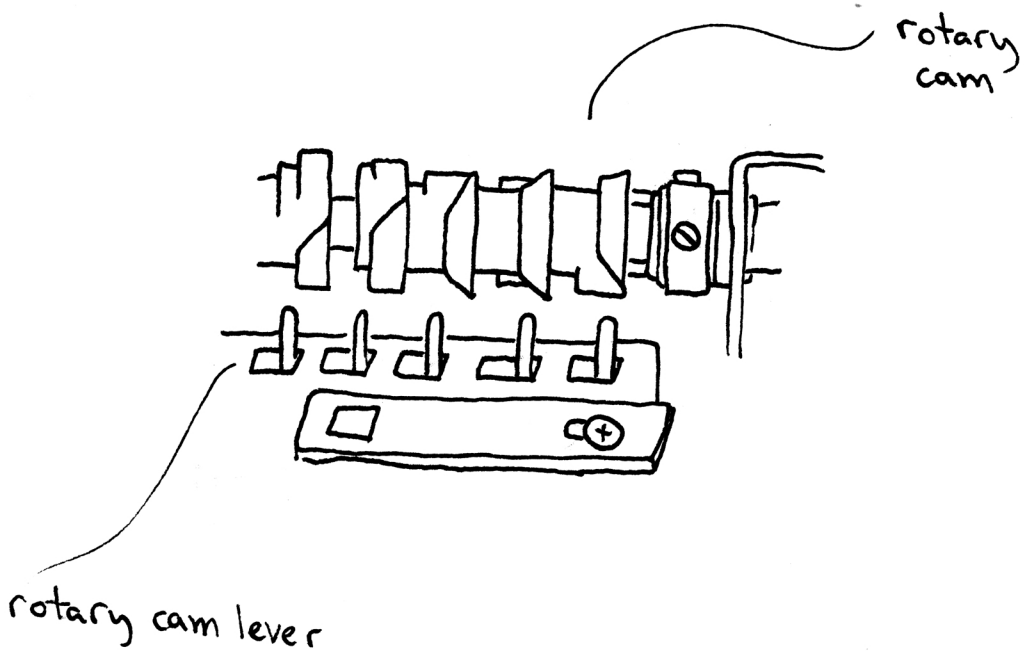
rotary cam lever

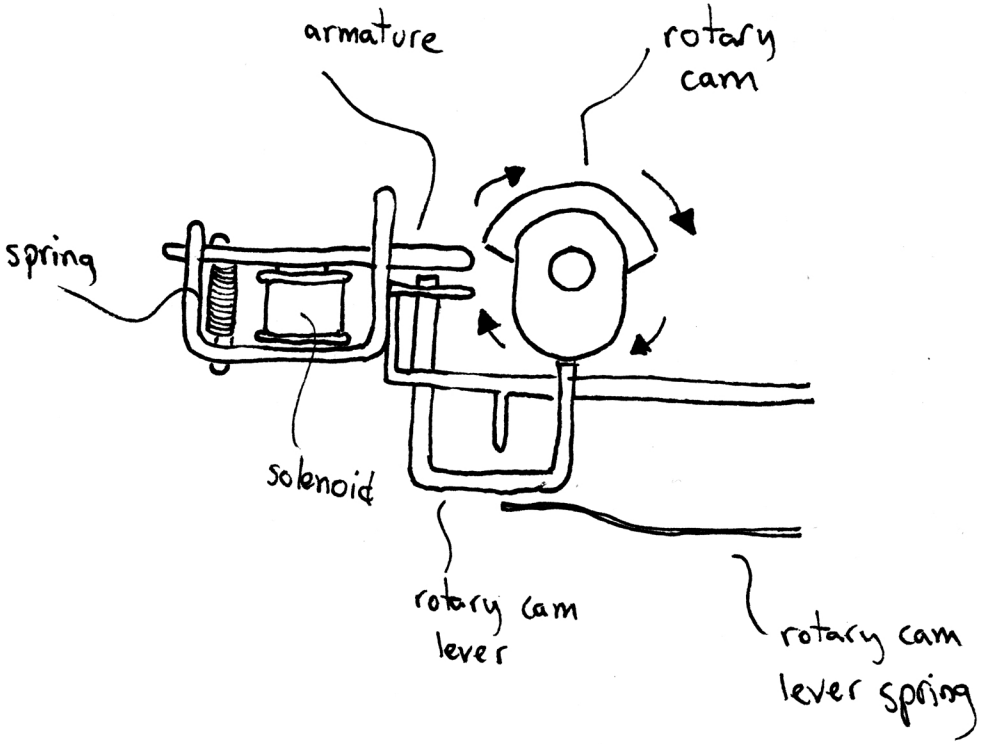


cam profile

cam nudges rotary cam lever which is connected to the needle selector plates which get nudged as a result

The rotary cams are shaped so that at a certain point they will nudge the rotary cam levers beneath them.





That is IF the solenoid doesn't pull down its armature, pressing the rotary cam lever down and out of the way of the rotary cam itself, well out of nudging range.

SO NOW all we need to do is turn the right solenoids on and off at the right time to knit a pattern.

BUTTT!!!!!!

There are 16 cam/solenoid mechanisms and 200 needles????

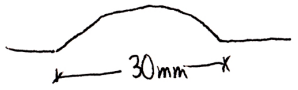
Stay with me!!!

Each cam is rotated slightly, so that the point that does the nudging is offset by about $\frac{360^\circ}{16} = 22.5^\circ$. This way, each cam nudges in sequence as they all rotate all together, driven by the cogs and timing belt, which are in turn driven by the carriage.

There are 16 cams, each connected to a needle selector plate (NSP). There are only 8 NSPs though, so each NSP is connected to 2 cams. For instance, NSP 1 is connected to cam 0 AND cam 8. NSP 2 is connected to cam 1 AND cam 9, and so on.

NOTE

The selection cam is about 30mm wide.



The distance spanned by 8 needles is also 30mm.

WHAT IS HAPPENING

It seems like, when the selection cam passes over a certain needle butt, that there are TWO possible cam/solenoids we could use to control it.

BUT!!! Remember that the cams are all offset, and that the two relevant cams are always rotated 180° relative to one another, so only ONE of them will have its "nudging point" about to nudge the rotary cam lever while the needle butt is still held down by the selection cam.

HOW do we know WHICH cam/solenoid tho???

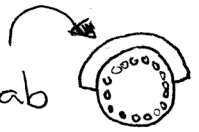
BELT PHASE, BABAYY,

We use "Belt Phase".

The timing belt has elongated holes spaced 8 needles apart.

The carriage attaches to these holes.

Depending on what position the timing belt (and therefore the angle of the rotary cams) is in before the carriage engages with it, either the first 8 or second 8 cams of the 16 will be rotated such that they will be able to control the first needle the carriage passes over at the end of the needle bed.

The Belt Phase signal, generated by the big tab  on the encoder disk (which spans 8 holes/needles), tells us which of these groups of 8 to choose.

For example, according to the next chart,

- If the carriage is all the way left at Needle 100, and the Belt Phase is LOW, it means the cams ae rotated such that Cam 1 (controlled by solenoid 1) will "nudge" while the carriage's needle selection cam is passing over Needle 100.

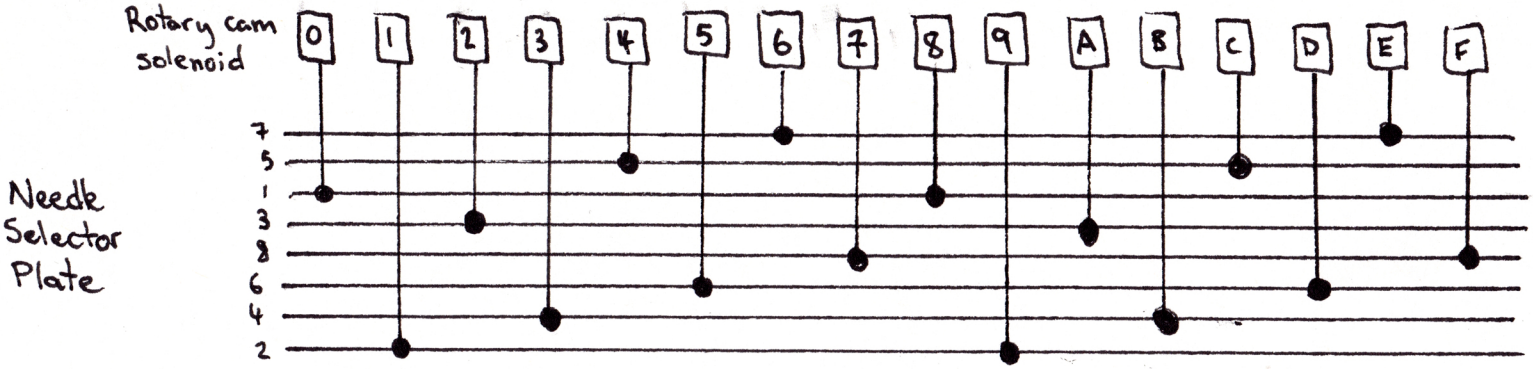
- If the carriage is all the way left at Needle 100, and the Belt Phase is HIGH, it means the cams are rotated such that Cam 9 (controlled by solenoid 9) will "nudge" while the carriage's needle selection cam is passing over Needle 100.

The rotary cam levers are themselves attached to rods called "Needle Selector Plate Operation Levers". When the rotary cam levers are nudged, so are these, and so are the corresponding needle selector plat

DOESN'T

So when a solenoid pulls down, the corresponding needle selector plate gets nudged...

The mapping of solenoid → rotary cam lever → needle selector plate operation lever → needle selector plate is



... and of course when THAT gets nudged, the corresponding needle shank that has been held down under one its tangs gets released, the needle butt springs up and is pushed to Position B by the carriage.

Needle Selection Chart!

Needles numbered w/ 0 in the middle of the machine like,

left ← ...4 3 2 1 0 1 2 3 4... → right

L = LOW
H = HIGH

Needle Selector Plate	Solenoid		Needles (left side)							Needles (right side)						
1	0	8	100	84	68	52	36	20	4		13	29	45	61	77	93
2	1	9	99	83	67	51	35	19	3		14	30	46	62	78	94
3	2	A	98	82	66	50	34	18	2		15	31	47	63	79	95
4	3	B	97	81	65	49	33	17	1		16	32	48	64	80	96
5	4	C	96	80	64	48	32	16		1	17	33	49	65	81	97
6	5	D	95	79	63	47	31	15		2	18	34	50	66	82	98
7	6	E	94	78	62	46	30	14		3	19	35	51	67	83	99
8	7	F	93	77	61	45	29	13		4	20	36	52	68	84	100
1	8	0	92	76	60	44	28	12		5	21	37	53	69	85	
2	9	1	91	75	59	43	27	11		6	22	38	54	70	86	
3	A	2	90	74	58	42	26	10		7	23	39	55	41	87	
4	B	3	89	73	57	41	25	9		8	24	40	56	72	88	
5	C	4	88	72	56	40	24	8		9	25	41	57	73	89	
6	D	5	87	71	55	39	23	7		10	26	42	58	74	90	
7	E	6	86	70	54	38	22	6		11	27	43	59	75	91	
8	F	7	85	69	53	37	21	5		12	28	44	60	76	92	

BP signal			
	L	H	left position sensor
	H	L	right position sensor

A Big Big Flow Chart of the Whole Thing

A person brings forward the number of needles that matches their pattern width and casts on.

Carriage starts moving from one end of the needle bed towards the other

left/right position sensor is passed and counting can begin

Carriage engages with the timing belt to drive the needle-counting mechanism + selection

needle counting begins

NEEDLE COUNTING

Timing belt —drives→ cogs —spin→ cam axle —spins→ encoder slit disc → two encoders offset by a ½ hole count holes, thereby counting needles and another encoder counts Belt Phase

As carriage moves, needle butts enter the channels on the underside

Needles that enter at Pos B (working position) → Pushed to yarn feeder A and pulled back

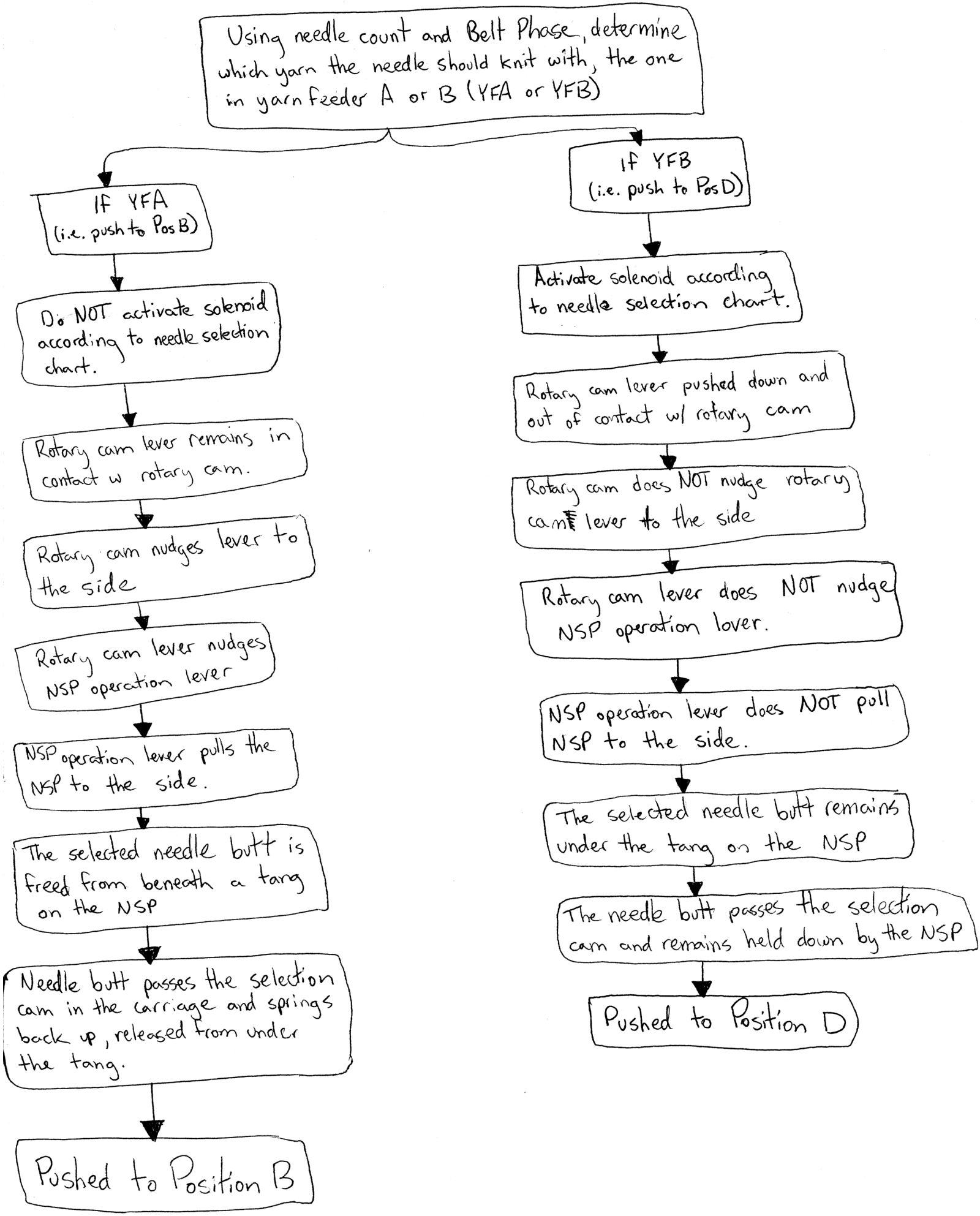
Needles that enter at Pos D (upper working position) → Pushed to yarn feeder B and pulled back

Needles entering at Pos A (non-working position) → Needles pass thru unmoved

Pos E → Hold current loop

Needles pass over the needle selection cam

Needle selection cam pushes needle butt down, forcing its shank beneath a tang on the corresponding needle selector plate (NSP)


Using needle count and Belt Phase, determine which yarn the needle should knit with, the one in yarn feeder A or B (YFA or YFB)
IF YFA (i.e. push to Pos B)
Do NOT activate solenoid according to needle selection chart.
Rotary cam lever remains in contact w rotary cam.
Rotary cam nudges lever to the side
Rotary cam lever nudges NSP operation lever
NSP operation lever pulls the NSP to the side.
The selected needle butt is freed from beneath a tang on the NSP
Needle butt passes the selection cam in the carriage and springs back up, released from under the tang.
Pushed to Position B
If YFB (i.e. push to Pos D)
Activate solenoid according to needle selection chart.
Rotary cam lever pushed down and out of contact w/ rotary cam
Rotary cam does NOT nudge rotary cam lever to the side
Rotary cam lever does NOT nudge NSP operation lever.
NSP operation lever does NOT pull NSP to the side.
The selected needle butt remains under the tang on the NSP
The needle butt passes the selection cam and remains held down by the NSP
Pushed to Position D